Contractor Report ARRAD-CR-88002

SYSTEMS ENGINEERING REVIEW AND DESIGN FOR A SMALL RESEARCH LABORATORY LOW-LEVEL RADWASTE PROCESSING SYSTEM

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A systems engineering review and design for a small scale laboratory low level radwaste processing system has been performed and the program has produced the following conclusions:

1. A volume reduction process has been prepared for each of eight categories of Armament Research, Development and Engineering Center (ARDEC) generated materials.

2. The radwaste processing system:

(a) Meets all known technical, legal, and safety requirements.
(b) Can also be used for the volume reduction of similar but nonradioactive wastes.
(c) Developed for ARDEC, could also be used by other Army facilities
(d) Gives a very significant volume reduction while improving on the safety of the overall radioactive (cont)

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waste disposal plan.

(e) Only requires electricity and compressed air for operation.

(f) Represents a ninety-three percent reduction of the present costs.

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INTRODUCTION

Background

The U. S. Army Armament, Munitions and Chemical Command (AMCCOM) at Rock Island, Illinois currently administers the radioactive waste disposal program for the entire U. S. Army by "directing the packaging, transportation and ultimate burial of unwanted radioactive material" at commercial waste disposal sites. The AMCCOM Radioactive Waste Disposal Safety Office responds to disposal requests from any Army element by providing assistance in packaging, shipping and burial container certifications. The Safety Office provides detailed instruction to the requesting agency on: how to package the low-level waste, the proper shipping instruction and how to complete the certification documents for container burial at a commercial site.

The number of U. S. Army installations having the potential for generating low-level waste (LLW) contaminated with pyrophoric unoxidized depleted uranium or tritium covers a broad area of the United States making the logistics for transporting and collecting LLW a costly undertaking. LLW is presently sent to an AMCCOM Safety Office established consolidation facility colocated at the Barnwell burial site, where it is more efficiently compacted and repackaged to conform to the strict requirements imposed by the burial site contractor.

The repackaged waste is then shipped directly to the adjacent burial site. The existence of this consolidation facility has markedly improved the efficiency with which packages of solid laboratory wastes coming from a wide geographical area can be effectively handled and buried. The cost involved in the burial of LLW is based upon burial volume (small for ARDEC at this time), weight and radioactivity (not applicable to Picatinny). The Barnwell disposal fee schedule starts with a standard charge per cubic foot of burial volume with additional surcharges for container weight and radioactivity of the shipment. In addition to

continued increases in burial fees at Barnwell, consideration must also be given to transportation and labor costs involved in shipping the LLW which amounts to about 60% of the total disposal costs.

Even when unoxidized, pyrophoric depleted uranium contaminated solid scrap, HEPA filters, aqueous solutions, oil and other contaminated materials associated with the Health Physics Operation are compacted and/or mixed with sand or concrete, the material remains pyrophoric in nature, and the possibility exists for both hydrogen build-up and self-sustaining combustion. An excellent paper that describes the fire potential that exists with uranium manufacturing wastes is shown in appendix A; although this paper was prepared some time ago (because of this, some of the regulatory descriptions are no longer applicable), it gives a good presentation of the pyrophoric nature of uranium scrap and describes basic preventative procedures.

The disposal of low-level radioactive wastes has been an increasing concern and an increasing cost for the Army in general and ARDEC, Picatinny Arsenal in particular. Reducing the volume of radwastes would reduce the cost of disposing of these wastes, and converting the wastes to a completely passivated nonpyrophoric ash would improve upon the safety of the disposal system.

A recently completed program for ARDEC, "A Feasibility Study for the Laboratory Reduction of Low-Level Radioactive Wastes," showed that a slow-burn ashing/passivation approach would effectively reduce the volume of most of the radwastes as well as convert the wastes to a passivated state. In addition, the study showed that a compactor could be used for volume reduction of those materials that could not be burned for reasons of toxicity. This study was Phase I of ARDEC's program to evaluate and solve their low level radwaste disposal system.

The low-level wastes of concern to ARDEC, Picatinny Arsenal, consists of pyrophoric, unoxidized depleted uranium and/or tritium contaminated cloth (cotton), wood, paper, toluene, pseudocumene, plastics, rubber,

leather, ion exchange resins, filters loaded with pyrophoric, unoxidized depleted uranium (such as HEPA filters), uranium scrap (including finely divided metallic saw turnings, chips, boring, sawdust, abrasive saw sludge. and fines), pyrophoric depleted uranium contaminated vacuum pump oil, unwanted but recyclable radioactive materials such as various types of pyrophoric penetrator rounds, aqueous solutions from holding tanks containing pyrophoric, unoxidized depleted uranium and other contaminated materials associated with the health physics operations.

Program Objective

The objective of this program was to provide a systems engineering review and design of a small research laboratory low-level radioactive waste processing system for supplying the critical information and assistance required in meeting the safety requirements and performance standards at ARDEC for the preparation for disposal of low-level radioactive waste. The goal of the processing system included a 25:1 reduction in the volume of solid wastes treated by ashing/passivation, over 99% passivation for wastes treated by the ashing/passivation processing, a 5:1 volume reduction for compaction, a 5:1 volume reduction for crushing liquid scintillation vials, a 100:1 volume reduction for certain contaminated liquid wastes and a method for recycling some types of radioactive materials.

Approach

The approach to the program was to design a state-of-the-art muffle furnace for slow-burn, ashing/passivation, volume reduction processing, a state-of-the-art quality compactor for volume reduction of non-ashable materials and a vial crusher for volume reduction of liquid scintillation vials after performing an evaluation of various concepts for each of the components. The designs and concepts that were revealed during the Phase I Feasibility Study were used in evaluating various approaches, and each radioactive material of concern to ARDEC was classified for either ashing/passivation, compaction, crushing, evaporation followed by

passivation or recycling based upon an analysis of each material. Various other features such as projected costs, layouts, physical restraints, and schedules were also included in this program.

Low-Level Radioactive Wastes Definition

Throughout this report, the term "low-level radioactive wastes" will be used. The low-level radioactive wastes generated at ARDEC are neither associated with any nuclear weapon grade material nor with highly radioactive reactor grade materials but rather are associated with the research, development and engineering with radionuclides such as pyrophoric depleted uranium used in kinetic energy rounds and tritium used in radioluminous light sources. As defined by the Nuclear Regulatory Commission in 10 CFR 71.4, the following definition of low specific activity will apply to our use of the term "low-level radioactive wastes":

"Low specific activity material means any of the following:

(1) Uranium or thorium ores and physical or chemical concentrates of those ores;

(2) Unirradiated natural or depleted uranium or unirradiated natural thorium;

(3) Tritium oxide in aqueous solutions provided the concentration does not exceed 5.0 millicuries per milliliter;

(4) Material in which the radioactivity is essentially uniformly distributed and in which the estimated average concentration per gram of contents does not exceed specified values (see 10 CFR 71.4);

(5) Objects of nonradioactive materials externally

contaminated with radioactive material, provided that the radioactive material is not readily dispersible and the surface contamination, when averaged over an area of 1 square meter, does not exceed specified values (see 10 CFR 71.4)."

TECHNICAL PROGRAM

Typical ARDEC Radioactive Wastes

The ARDEC Safety Office recently (December 1987) prepared a shipment of low-level radioactive wastes for burial. The shipment consisted of 22 barrels of paper/wood/cloth wastes, 22 barrels of plastic wastes, 10 barrels of source wastes (such as Co^{60}, Ce^{137}, etc.), 8 barrels of armor plate (contaminated with pyrophoric, unoxidized depleted uranium), 4 barrels of filters and 1 barrel of pyrophoric, unoxidized depleted uranium manufacturing wastes; all of the barrels were 55-gallon size. Figure 1 is a "pie" diagram showing the relative amount of each of the wastes.

Of the 67 barrels included in the shipment, all but the 8 barrels of armor plate and some of the source barrels could have been volume reduced by either ashing or compaction. Using these volume reduction techniques, it is estimated that the shipment could have been made in 20 barrels, which represents a 70.1% volume reduction.

In addition to the materials in the above shipment, ARDEC also has radwastes consisting of rubber, leather, ion exchange resins, tritium, toluene, pseudocumene, pyrophoric unoxidized depleted uranium, contaminated laboratory trash, contaminated vacuum pump oil, recyclable pyrophoric penetrators, ingots, pyrophoric scrap, pyrophoric, unoxidized depleted uranium contaminated collecting tank fluids and liquid scintillation vials.

Classification of Materials

In the preparation of a system for the disposal of radioactive wastes, each of the radioactive materials of interest to ARDEC was classified into one of the following categories:

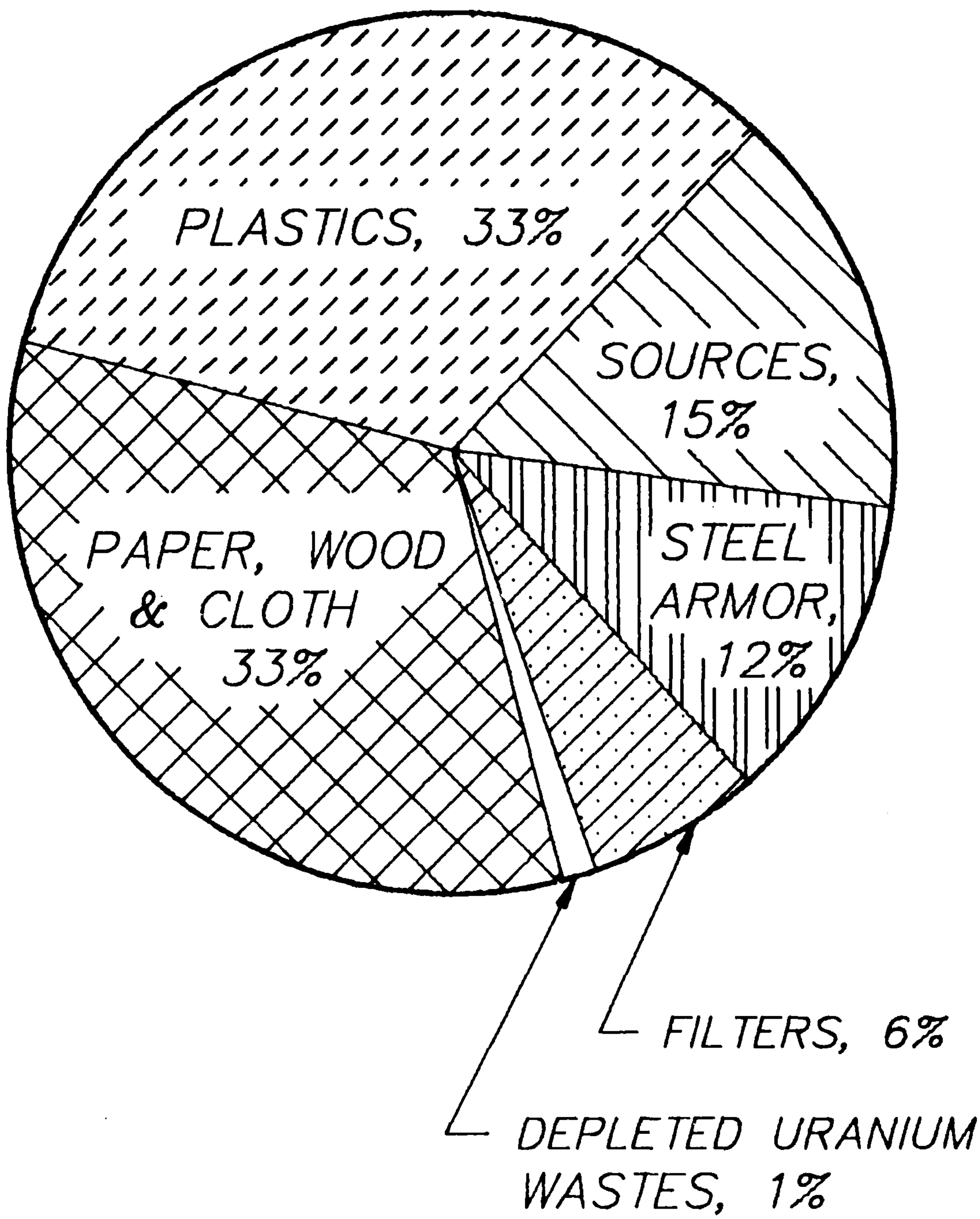


Figure 1. Pie diagram showing the relative amount of radwastes for a recent ARDEC shipment.

Category	Requirement
Ashing/Passivation	Solids that are burnable without releasing significant amounts of toxic gases.
Compaction	Solids that are not burnable because of toxicity reasons but are compactable.
Crushing	A special category for glass liquid scintillation vials.
Filters	A special category for filters that are to be first ashed/passivated and then compacted.
Non-Burnable and Non-Compactable	Solids that are neither burnable or compressible. This includes armor plate, some source materials etc.
Evaporable Liquids	Liquids that can be evaporated and passivated without releasing significant amounts of toxic gases.
Non-Evaporable Liquids	Liquids that can not be evaporated for reasons of toxicity.
Recyclable Mat'ls	Solids that can be reused, but require special packaging or other considerations.

In the Phase I Feasibility Study, an evaluation of the low-level radioactive wastes in the first two categories above was undertaken to determine which of these materials could be ashed and which would have to be compacted. The analysis indicated that only plastics, rubber, leather and ion exchange resins were shown to produce toxic gases when ashed, and as a result, a literature search was conducted in the present program to

quantitatively determine the amount of each toxic gas produced by ashing these materials. Two reports were found (from the Phase I Study) in which mixed wastes of known compositions were burned under controlled conditions and the gases produced were identified and quantitatively measured. In both of these reports it was possible to relate the toxic gases to the levels of specific materials in the waste. By knowing the exact composition of the incoming wastes and off-gases, the rate of combustion and the air flow, it was possible to determine the concentration of toxic gas produced by the combustion of one pound of waste per hour; this concentration was then normalized for an air flow of 1000 CFM (this is the design air flow of the muffle furnace ventilation system, as discussed later). These reports were used to generate data for PVC and rubber, as well as wood, paper and cloth.

No reports could be found that gave quantitative data on the off-gases for the combustion of either leather or ion exchange resins. For these materials, calculations were carried out based upon a knowledge of the chemical structure of both materials.

Considering the relatively low volume of materials to be ashed in the ARDEC system, it became apparent very early in this evaluation that the only toxic gases of concern would be SO_2, HCl and NO_x. In table 1 on the next page, the concentration of each of these gases is shown for each material of interest (the off-gases from wood, paper and cloth are included for comparison). In addition, the maximum allowable concentration is also shown.

The data in table 1 can be used to calculate the maximum hourly ashing rates for each material, based upon the amount necessary to reach the maximum allowable concentration of the appropriate gas. This was done and the results are shown in table 2.

Since the data shown in the above two tables are either calculated values or values taken from the operation of a radwaste system not entirely equivalent to the ARDEC design, the data should be viewed only

Table 1. Concentration of toxic off-gases

	Concentration in PPM (per pound ashed per hour) SO_2	HCl	NO_x
Maximum Allowable Concentration (see note)	30	50	10
Material:			
Wood, Paper & Cloth	.05-.15	-	-
Rubber	370	-	-
PVC	-	152	-
Leather	2	-	11
Cation Exchange Resins	10	-	-
Anion Exchange Resins	-	20	-
Contaminated Oils	4	-	-

Note: Dangerous Properties of Industrial Materials, 5th Edition, N. I. Sax, Van Nostrand Reinhold, N.Y., 1979.

Table 2. Maximum hourly ashing rates

Material	Maximum Hourly Ashing Rate (see note)
Wood, Paper & Cloth	200-600 lbs. (91-273 Kg.)
Rubber	.08 lbs. (.036 Kg.)
PVC	.33 lbs. (.15 Kg.)
Leather	.9 lbs. (.41 Kg.)
Cation Exchange Resins	3 lbs. (1.4 Kg.)
Anion Exchange Resins	2.5 lbs. (1.1 Kg.)
Contaminated Oils	7 lbs. (or, 1 gallon)

Note: Based upon reaching the maximum allowable concentration of a specific toxic gas.

as a general expectation of the ARDEC system. Considering the data in the tables, we conclude that rubber and PVC should not be ashed and that only very small amounts (on the order of one pound, or less) of leather and ion exchange resins could be considered for ashing in the ARDEC system. With regards to liquids, the table also shows that about 1 gallon per hour of contaminated pump oil could be processing in the system; while not shown in the table, the processing of unlimited amounts of aqueous solutions contaminated with pyrophoric, unoxidized depleted uranium could be performed since no toxic off-gases are involved.

There is another very important feature that should be considered when evaluating the desirability of ashing materials that produce significant levels of toxic gases. The ventilation system on the ashing furnace is designed to operate at 1000 CFM. While all concentrations for the toxic gases are based upon a dilution with 1000 CFM of clean air, any breakdown in the air flow (power outage, frozen fan shaft, etc.) would drastically increase the toxic gas concentration. Thus, a system that normally operates well within the allowable concentration limits for toxic gases could easily produce very dangerous concentrations with a stoppage in the air flow. As a result, we do not recommend the ashing of even small amounts of rubber, PVC, leather and ion exchange resins. These materials should be volume reduced in the compactor.

In high volume radwaste disposal systems that are based upon some type of burning, a scrubber is always installed to prevent the release of any toxic gases to the environment. The use of a scrubber is not being recommended for the present design because of both the cost involved and the problems associated with the scrubber liquids (mixtures of acids and radioactive components).

Using the results of this section, each of the radioactive materials of interest to ARDEC has been classified by category, and the results are shown on the following page:

Category	Requirement
Ashing/Passivation	Wood, paper, cloth (cotton) and pyrophoric, unoxidized depleted uranium manufacturing wastes.
Compaction	Plastics, rubber, leather, and ion exchange resins.
Crushable	Liquid scintillation vials.
Filters	HEPA filters and pre-filters.
Non-Burnable and Non-Compactable	Armor plate, some source materials, etc. Although these materials are not compactable per se, they can be included in the compaction processing so as to minimize their packaging volume.
Evaporable Liquids	Toluene, tritium, pseudocumene, radioactive contaminated pump oil and aqueous solutions containing pyrophoric, unoxidized depleted uranium.
Non-Evaporable Liquids	None known of any significant volume to ARDEC but liquids such as acid solutions would come in this category. These liquids could be first neutralized and then evaporated.
Recyclable	Solids such as penetrators.

Processing Description

Based upon the results established in both present study and the Phase I Feasibility Study, we are proposing a radwaste processing system

consisting of ashing/passivation for materials that can be burned (without toxicity problems), compaction for materials that can not be burned, a combination of these two procedures for filters, vial crushing followed by passivation for liquid scintillation vials, evaporation followed by passivation for contaminated evaporable liquids (this includes aqueous solutions and oils) and recycling for certain materials. Each of the processes are described in the sections that follows.

Radwaste Identification & Manual Separation

Incoming radioactive wastes would be received in a designated area, and identification and manual separation of the wastes would be done. Burnable solids including wood, paper, cloth (cotton) and pyrophoric, unoxidized depleted uranium wastes would be separated from the other solid materials including plastics, rubber, leather and ion exchange resins. The non-burnable/non-compactable materials that are to be included into compaction, such as armor plate used as targets and contaminated with pyrophoric unoxidized depleted uranium, would be included with the compactable materials while those requiring special packaging (some of the source materials) would be separated from the rest. Recyclable penetrators in original wooden boxes would require manual segregation. Filters (both pre-filters and HEPA) would also be separated for later processing. The evaporable liquids (toluene, tritium, pseudocumene and aqueous solutions containing pyrophoric, unoxidized depleted uranium) would also be segregated. Liquid scintillation vials would also require special separation.

Ashing, Vacuum Transfer and Solidification

The ashing/passivation is to be done in a muffle furnace using two heating stages. In the first or charring stage, the material is heated to about 1200 degrees F (649 degrees C) in the absence of oxygen and all the volatile constituents are released. In the second stage, the

material is heated to about 1600 degrees F (871 degrees C) with a controlled amount of oxygen, and complete passivation occurs.

After cooling to ambient temperature and removal from the furnace, the radioactive ashed material is analyzed to verify that passivation is complete. A procedure for performing this determination was included in the Phase I Study. Following the verification, the ashed material is transferred to 55-gallon drums using a vacuum transfer technique. The equipment used for the transfer has high efficiency filters that prevent the release of any radioactivity into the environment.

Finally, a solidification process is used to convert the nonpyrophoric, radioactive ashed powder to a solid form that can be shipped for burial. This solidification is done inside 55-gallon drums which later become the shipping containers.

Compacting

A high quality compactor is used to volume reduce materials that are not burnable. The compactor also uses high efficiency filters that prevent any radioactivity from entering the environment. Compaction is done into either 55-gallon or 85-gallon drums, and these drums are used for shipment.

Crushing

A vial crusher is used to crush and pulverize liquid scintillation vials. These vials will contain only solids at the time of their volume reduction, and the crushed/pulverized vials will be passivated along with their contents.

Filters

The standard high-quality filter in the nuclear industry is a

HEPA (High Efficiency Particulate Air) filter. Both HEPA and normal pre-filters will first be ashed and passivated in the furnace, and then volume reduced in the compactor. A special attachment to the compactor allows for compaction of HEPA filters in 85-gallon drums.

Evaporation/Passivation

The evaporable, contaminated aqueous solutions and oils will first be evaporated using the muffle furnace; the same collection tray that is used for ashing solids will be used for evaporating the liquids. After evaporation is completed at appropriate temperatures (about 180 degrees F, or 82 degrees C, for aqueous solutions containing pyrophoric, unoxidized depleted uranium and somewhat higher temperatures for the oils) passivation will be done in a similar manner as used for the solids. After passivation, the processing is the same as used for solids that are ashed.

Recyclable Materials

Certain materials like pyrophoric, unoxidized depleted uranium penetrators will be recycled. These materials will be packaged in their original manner (wooden boxes in the case of penetrators) and either sent to the appropriate Army facility for future use or returned to their manufacturer.

Allowable Radioactivity Considerations

Past experience with the incineration of pyrophoric, unoxidized depleted uranium manufacturing wastes has shown that the surface radioactivity of a 55-gallon drum filled with 850-lbs. (386-Kg.) of uranium oxide, U_3O_8, is about 3 mr/hr. The allowable surface radioactivity is 200 mr/hr, and even with 100% of depleted uranium wastes, the radioactivity of the drums is less than 2% of the allowable. In most cases, the ashing/passivation of items like wood, paper, and cloth will result in a surface radioactivity far less than the 3mr/hr

found with uranium oxide; likewise, the surface radioactivity after compaction of contaminated plastics, rubber, leather, ion exchange resins and filters will be well under 1 mr/hr. Therefore, the processing outlined above will produce drums for shipment that are far below the allowable limit of radioactivity.

Safety Considerations

The general concept of passivating metallic uranium to uranium oxide has been done for a number of years. From 1979 until the present, Aerojet Ordnance Company has incinerated over three million pounds of pyrophoric, unoxidized depleted uranium (to form uranium oxide) without any safety or health physics problems. Thus, the approach being recommended for ARDEC can be achieved without introducing any significant safety or health physics hazards.

Study Radwaste Processing System

The feasibility study performed in Phase I of this program was used to identify and evaluate several different types of small research laboratory low-level radwaste processing systems that could be used by ARDEC. In addition, the low-level radwaste depositories at Barnwell, SC, Richland, Washington and Beatty, Nevada were contacted to review their current acceptance criteria for low-level radwastes. The conclusion was made that there wasn't any technical, legal or safety reasons for not using a muffle furnace for ashing/passivation of some types of radwastes and a compactor for other types of radwastes that are not ashable (for reasons of toxicity). Thus, the processing outlined in the previous sections appears to meet all the technical, legal and safety requirements for a low-level radwaste disposal system.

Flow Chart

A flow chart for processing all radwaste materials of interest

to ARDEC is shown in figure 2; the flow chart includes all the burnable, compactable, crushable or evaporable materials.

Ashing-Passivation System

Each of the three processes for the ashing-passivation system are described in this section.

Muffle Furnace Design

The following criteria were ARDEC requirements for the muffle furnace:

(a) A maximum continuous uniform operating temperature sufficient to completely oxidize depleted uranium and thoroughly ash other materials.

(b) A HEPA filtered ventilation system.

(c) Rapid heat-up and rapid recovery.

(d) High energy efficiency with reduced power requirements.

(e) A collecting tray inside the furnace for oxides, ashes and debris.

(f) Minimum four cubic feet chamber to handle one cubic foot loads or large 24-inch x 24-inch x 12-inch HEPA filters.

(g) An easily opened insulated door to readily permit loading with secure door closures.

(h) Base cabinet for controls and power supply components.

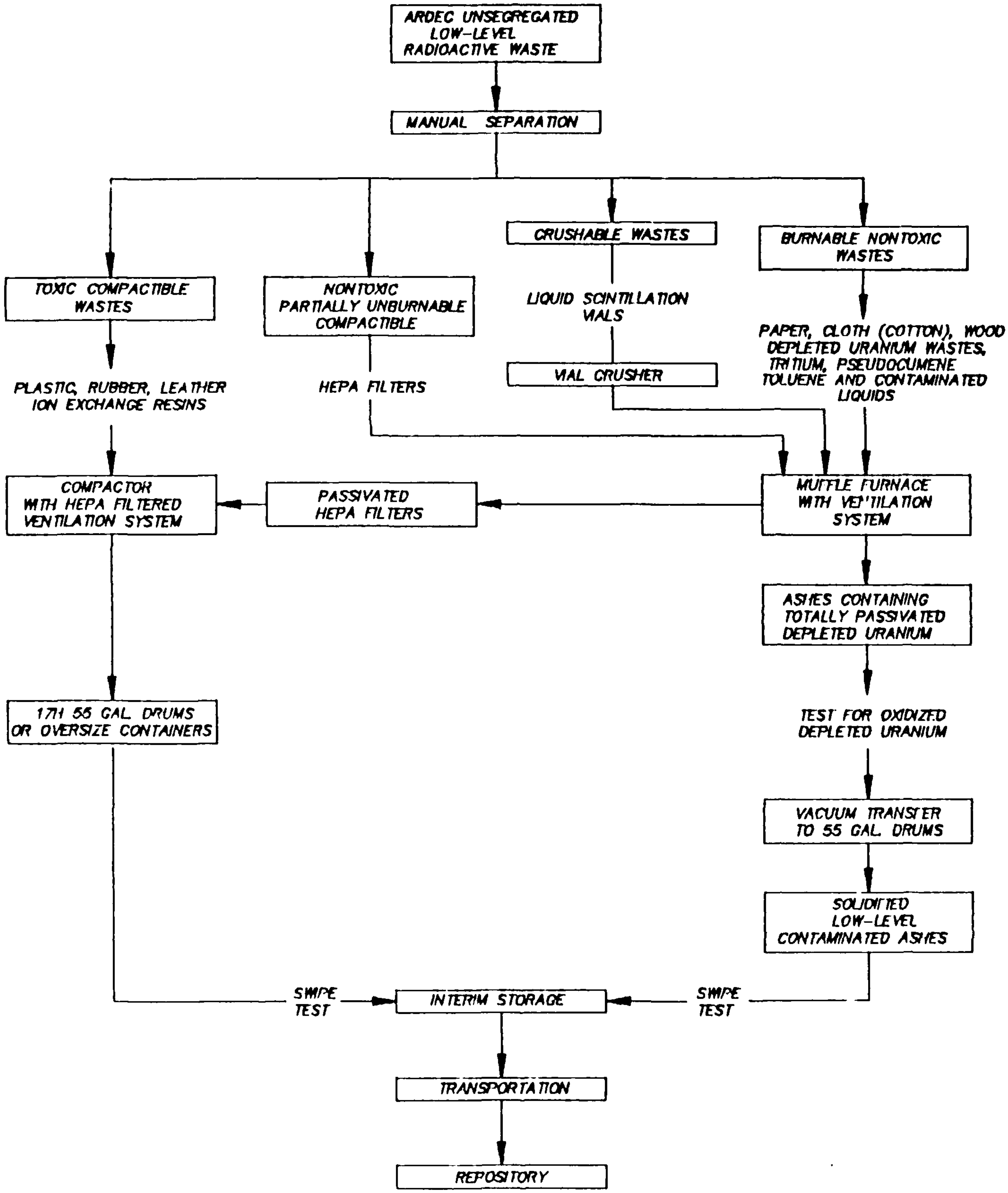


Figure 2. Flow chart for all burnable, compactable, crushable and evaporable materials

(i) Microprocessor/programmer furnace temperature control system.

(j) Lightweight insulation.

(k) Fail-safe mechanisms such as interlocks, temperature and access controls.

(l) Accurate temperature measuring devices.

(m) View ports as necessary.

(n) Long lasting heating elements.

(o) Low operating costs.

(p) Low shell temperature.

(q) High quality, high performance ratings.

(r) A storage drawer under the furnace.

(s) Simple, safe, uncomplicated, dependable, reliable and scientifically engineered features.

Using these criteria, a single chamber muffl furnace was designed for operational temperatures up to 2000 degrees F (1093 degrees C). which is the upper limit for passivation that was established in the Phase I Study. The working chamber can accommodate either 30-lbs. (13.6 Kg) of wood or a 24-inch by 24-inch by 12-inch HEPA filter. The furnace has a sealed plug door with inlet and exit ports for controlled amounts of air and view ports for observing the contents during processing. Electrical heating elements are used, and a rapid cooling mechanism is included. An after burner is used to ignite any combustible off-gases, and ceramic fiber is used as an insulating material. The

temperature controlling is done with a microprocessor, and any combination of heating rates, temperatures, holding times and cooling cycles can be programmed in the controller. The ventilation system is equipped with a HEPA filter having a 99.97% minimum filtering efficiency for particles 0.3 microns and larger. The ductwork in the ventilation system is stainless steel, and experience with other systems that burn similar materials has been shown that any potentially dangerous products of combustion, such as hydrochloric acids, do not degrade the ductwork.

A 30-inch by 30-inch by 15-inch high collection tray is provided for the ashing/passivation container. Since this tray is a watertight container, the tray could also be used for the evaporation and passivation of contaminated liquids.

An engineering specification was prepared for the muffle furnace and the specification is shown in appendix B.

While the muffle furnace has been designed to ash radioactive materials, the furnace could also be used for ashing non-radioactive combustible materials as well (provided the toxicity considerations are satisfied).

Vacuum Transfer

After the ashing cycle is completed, some method will be required for transferring the nonpyrophoric, radioactive ash from the collection tray to a suitable container. We are recommending the use of a vacuum transfer system which can be done with a high powered vacuum cleaner (this is the current industry standard method of transferring dry ash powders). This method limits any airborne exposure to minimal levels. Other methods of transfer would be to wet the ash first (to stop airborne release) and then to transfer with scopes or shovels to an appropriate container. Two major suppliers of HEPA filtered vacuum cleaners to the nuclear industry were contacted, and a brief review of their products is shown on the next page.

Hako Minuteman. Several sizes of electric and air powered HEPA filtered vacuum cleaners that will provide 99.99% air exhaust cleaning efficiency down to .12 micron particle size are available including 4, 6, 15, 30 and 55 gallon drum sizes. The 55 gallon size would probably be the most useful since the ashed wastes could be directly transferred from the collecting tray to the final storage/transportation container. The electric model (MX-1000-55) provides 100 cfm of suction and a static lift of 130 inches of water. The air model (X-703-55) provides 166 cfm of suction and a static lift of 180 inches of water. The air system needs 90 psi and 42 SCFM of air to operate. Assuming the compressed air is available, the increase in efficiency and limited mechanical parts makes this a better option. The smaller size units would require open air transfer of the collected material when preparing for solidification, and therefore, a potential air exposure problem exists. This concern and the increase in materials handling make the smaller sizes undesirable. Several types of accessories and options are available to meet any vacuum needs.

The address and telephone number for Hako is as follows: Hako Minuteman, Inc., 111 South Route 53, Addison, IL 60101, (312) 627-6900.

Nilfisk of America. Electric vacuum cleaners in 3, 5, 12 and 18 gallon capacities are available, and there are no air driven options. Although these units do not fit on the top of a standard 55 gallon drum for a direct transfer of ashed wastes (as does the Hako models), a separator top is available as an accessory. The best suited model would be the GS 82 which has 191 cfm suction and 75 inches of water lift. All units are HEPA filtered at an efficiency of 99.99% at .12 micron particle size. Various options are also available with these models.

The address and telephone number for Nilfisk is as follows: Nilfisk of America, Inc., 300 Technology Drive, Malvern, PA, 19355, (215) 647-6420.

Recommendation. Based upon and analysis of the above vacuum cleaning systems, we are recommending a Hako Minuteman, Model X-703-55 (air powered) for used at ARDEC.

Solidification

Current burial site regulations require that all ashed radioactive materials be solidified, granulated or treated in such a manner as to be rendered non-dispersible in air. The three most widely used ash stabilization methods are (1) using accepted liquid solidification media in low concentrations to bind the wastes, (2) mechanical agglomeration and briquetting techniques and (3) spraying with binding material. The stabilization method. The selected method should minimize any volume increase and the processing must be done in a cost effective manner. These two considerations coupled with the very low annual volume of expected radioactive ash at ARDEC, eliminates most of the mechanical agglomeration, briquetting techniques, and spray binders since these systems usually require large initial capital expenditures that are designed for high volume situations.

Therefore, we are recommending that the next phase of this overall program evaluate a system for solidification that can handle the low volume of nonpyrophoric, radioactive ashed material without a major capital investment. This will most likely involve the use of liquid solidification media in low concentrations to bind the ashed wastes in 55-gallon drums that later are the shipping containers. The technique to completely mix the wastes with the binding agent will probably involve some type of mechanical rotation, but this will have to be established.

Compactor

Compactor Requirements

The following requirements were established by ARDEC for the compactor:

(a) A compression force of at least 40,000 pounds (20 tons or 18,182 KG).

(b) Motor pump, all electric and hydraulic components.

(c) All steel arc welded construction.

(d) Stainless steel hood (12 gauge minimum).

(e) Stainless steel platen for 55 and "oversize" drums.

(f) Shroud (12 gauge minimum) that encloses the drum to prevent external contamination.

(g) Ventilation system consisting of a prefilter (40 % efficiency) and a nuclear grade HEPA filter (99.99% efficiency for 0.3 micron particles and larger), fan and accessories.

(h) Front extension to allow moving the drum in and out of the compactor.

Compactor Design

Three major manufactures of compaction equipment in the nuclear industry were contacted to evaluate the best state-of-the-art compactor for ARDEC's needs. The three manufactures were as follows:

1. Consolidated Baling Machine Company
   156-166 Sixth Street
   Brooklyn, NY 11215-3193
   (718) 625-0928

2. S & G Enterprises, Inc.
5626 North 91st Street
Milwaukee, WI 53225
(414) 464-5310

3. Container Products Corporation
P. O. Box 3767
Wilmington, NC 28406
(919) 392-6100

Initially, each manufacturer's models were reviewed, and for each manufacturer the model was selected that provides the closest match to the ARDEC requirements. The manufacturer/model are as follows: Consolidated Bailing Model DOS-RAW-W-2, S & G Enterprises Model 55 ER, and Container Products Model D-40.

All three of these models offer totally enclosable HEPA filtered compaction chambers which will meet NRC requirements for compaction of radioactive waste. Each of the models can also accommodate the oversize 85 gallon drums that will be used to compact HEPA filters. Larger compaction platens can be purchased for use with 85 gallon drums and on most presses you can switch back and forth and compact into either a 55 or 85 gallon drum by attaching the correct platen. The three models differ in price, space requirements and optional features such as drum support plates and rolling extenders to allow easy movement of the drums in and out of the machine.

A summary of these models and the ARDEC requirements are shown in the table on the next page. When costs are NOT considered, the Consolidated Bailing and Container Products models both appear capable of meeting ARDEC's requirements. The S&G Enterprises model is not being recommended since the drum support plate and roller extensions are not available for the 85 gallon drum option (as may be used by ARDEC for compacting HEPA filters). When considering costs, the Consolidated Bailing model appears to be the optimum selection.

SUMMARY OF COMPACTOR FEATURES

ARDEC Requirement	Manufacturer and Model: Consolidated Bailing, DOS-RAW-W-2	S&G Enterprises, 55 ER	Container Products, D-40
1. Compaction Force	20 ton	30 ton	20 ton
2. Dual Capacity, 55/85 gal.	yes	yes	yes
3. HEPA Filtration, Amount Air Flow	yes 410 cfm	yes 800 cfm	yes 1000 cfm
4. Pressure Gauge across HEPA	optional item	optional item	yes
5. Ventilation Enclosure	completely enclosed	completely enclosed	completely enclosed
6. Compaction Chamber Size	30"(w)x50"(h)	32"(w)x50"(h)	unknown
7. Space requirements	39"(w)x47"(d) x103" high	36"(w)x39"(d) x128" high	49"(w)x59"d x103" high
8. Additional Space for Ventilation Equipment	none	2'(w)x5"6"(1)	none
9. Construction Material	heavy gauge steel	heavy gauge steel	heavy gauge steel
10. Electrical Supply	3 phase 240/480	3 phase 240/480	3 phase 240/480
11. Safety Interlocks	yes	yes	yes
12. Drum Support Plates/ Roller Extensions	standard features	option for 55-gal only	standard features
13. Other Options	none	bottom lock	none

We have prepared an engineering specification for the compactor, and the specification is shown in appendix C.

Vial Crusher

The vial crusher to be used for the volume reduction of liquid scintillation vials had to have the capability of crushing the 20mm vials used by ARDEC for tritium swipe testing (and, possibly, depleted uranium swipe testing in the future). Vial crushers of this type are commercially available, and two potential suppliers, see below, were contacted.

1. C. S. Bell Company
   170 West Davis Street
   Tiffin, Ohio 44883
   (419) 448-0791

2. B/R Instrument Corporation
   P. O. Box 7
   Pasadena, Maryland 21122
   (800) 922-9206

Both manufacturers produce a vial crusher designed for top feed and bottom discharge into a collection container, and both types would probably require some special framework and mounting brackets. We are unable at this time to recommend one supplier over the other.

An engineering specification for the vial crusher has been prepared and is shown in appendix D.

Cost Effective Analysis

A cost effectiveness analysis for ashing/passivation and compaction was conducted. The analysis used annual waste estimates from ARDEC, volume reduction levels established from the Phase I program and cost

estimates for transportation and burial at the Barnwell, South Carolina site.

ARDEC presently creates about 30 barrels (55 gallon size) of low-level radioactive waste a year; in addition, annual waste disposal would also include about 3 HEPA filters and 7 pre-filters. Of the 30 barrels, about 22 of these will be ashable and the other 8 will be compactable. The cost analysis below assumes a 25:1 volume reduction for ashing, a 5:1 reduction for compaction, as seen in the Phase I feasibility report, and a 100:1 volume reduction for evaporating contaminated liquids. The burial costs used in this analysis were received from ChemNuclear for burial at Barnwell, SC (effective 1-1-88), and the transportation costs were obtained from Tri State Motor Carrier.

ANNUAL BURIAL AND TRANSPORTATION COSTS FOR LOW LEVEL RADIOACTIVE WASTES

Present Procedure	With Ashing Compaction and Evaporation
55-Gallon Drums:	
22 barrels ashable	.88 barrels after ashing
8 barrels compactable	1.6 barrels after compaction
30 barrels x 7.5 = 225 ft^3	2.48 barrels x 7.5= 18.6 ft^3
3 HEPA Filters:	
4 ft^3 x 3 =12 ft^3	1 ft^3 x 3 = 3 ft^3
7 Pre-Filters:	
1.33 ft^3 x 7 = 9.33 ft^3	.33 ft^3 x 7 = 2.33 ft^3

Contaminated Liquids:

ARDEC has about 1000 gallons of contaminated aqueous solutions and about 8 gallons of contaminated pump oil each year that require disposal (annual total of about 1008 gallons). Using normal procedures, about 20 gallons of contaminated liquids could be used for solidification in a 55-gallon drum. Therefore,

1008 gal/20 gal x 55 = 2772 gallons	negligible
= 369 ft^3	

Total Volume:

615 ft^3	23.9 ft^3

Annual Burial Costs, Barnwell, SC ($53.32/$ft^3$, 1988 costs):

615 x $53.32 =	$32,792	23.9 x $53.32 =	$1,274
County Tax =	309	County Tax =	30
Total	$33,101	Total	$1,304

Annual Transportation Costs:

Since ashing, compaction and evaporation only produces about 4% of the volume as with present methods, we estimate the transportation of the wastes for burial would be at three year intervals instead of semi-annual without ashing or compaction.

$2,734	$456

Total Annual Burial and Transportation Costs:

$35,835	$1,760

Processing Costs:

The total costs for ashing-compaction should also take into account the cost of the ashing-passivation processing. For this calculation, we are assuming an eight hour cycle to go from ambient to 1400 degrees F, or 760 degrees C, (which consumes about 6 KW per hour, or 48 KW-hr) an eight hour cycle to go from 1400 to 2000 degrees F, or 760 to 1093 degrees C, (at about 8 KW per hour, or 64 KW-hr) and an eight hour cycle to cool to ambient (about 1 KW per hour, or 8 KW-hr). Using the expected electrical costs for ARDEC in 1988 as $.081/KW-hr, the total cost for one processing cycle would be 120 KW-hr x $.081 = $9.72. With about 100 ashing-passivation cycles per year, the annual costs would be about $972. Thus, the total costs including the processing costs becomes,

$34,863	$2,508

Annual Savings With Ashing and Compaction:

The annual savings with ashing and compaction is $32,355, which represents an 93% reduction over the costs using present methods.

Evaluation of Constraints

After on-site inspections of the available ARDEC Safety Office facilities, the conclusion was reached that the muffle furnace and compactor should be located in Building 312 (alongside 320). Building 312 has the required ceiling height and floor space; in addition, the use of this new building for the radwaste system would not present any problems (such as contamination) with the scientific instruments located in 320.

The following utilities will be required for the operation of the radwaste processing system in Building 312:

Electrical Power Requirements

The muffle furnace will require 220/240 volt, 3 phase, 100 KW.

The ventilation fan motor will require an additional 220/240 volt, 3 phase, 5 KW.

The compactor will require 220/240 volt, 3 phase, 14 KW.

The vacuum transfer system cleaner will require 110 or 220 volt, 3 phase, 2 KW.

The vial crusher will require 115 or 230 volt, 5 KW.

Compressed Air Requirements

90 psi and 42 SCFM (surface cubic feet per minute) will be required for the vacuum transfer system.

Natural Gas Requirements

Natural gas will not be required for any of the equipment.

Water Requirements

While water will not be required for any of the equipment, process water should be available in the building for cleaning purposes. A slop sink should also be provided (ARDEC does not want drains in this building).

Heating and Ventilation Requirements

The ventilation system on the processing system will be exhausting about 1000 CFM of air from the building. Therefore, there should be provision for this amount of air supply (in addition to that needed for personnel and other considerations). The existing engineering specifications for building 312 specify two roof vents that can each supply 1000 CFM, and this might satisfy the requirement for the processing ventilation system. It is recommended that this situation be

reviewed with ARDEC Plant Engineering to determine the inlet ventilation requirements.

The need or desirability of having a heating/cooling system in building 312 should also be reviewed with Plant Engineering.

Proposed Layout

As discussed in the previous section, Building 312 is being recommended as the location of the radwaste processing system. This building is a newly constructed cement block building about sixty feet by thirty feet and with seventeen foot high walls. A bridge crane is to be installed for materials handling in the near future, and an eight foot by eight foot access door exists.

Based upon discussions with safety office personnel, the West corner of the building is being recommended as the specific location of the radwaste processing system, see figure 3. Two possible arrangements for the equipment are shown in figures 4 and 5. The location of the required electrical and compressed air outlets is shown on both figures 4 and 5.

Projected Costs

Muffle Furnace

The estimated costs for the muffle furnace are given below. The estimate is based upon starting fabrication in March 1988; all of the items fabricated from chrome nickel steel are rapidly increasing at the present time, and future estimates may reflect this increase in costs.

Muffle Furnace & HEPA Ventilation System		$103,135.00
Delivery		4,470.00
Installation		4,160.00
	Total Estimated Costs	$111,765.00

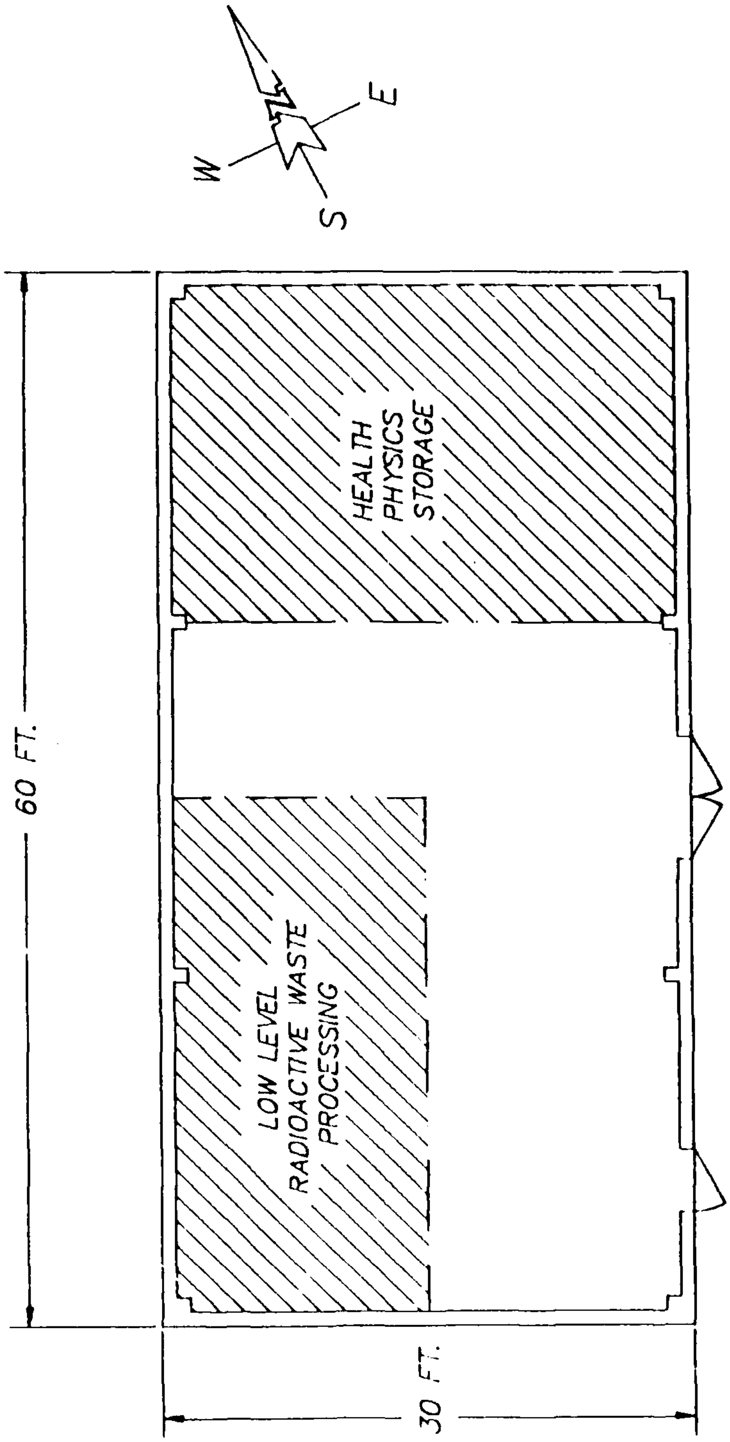


Figure 3. Location of the radwaste processing system in Building 312

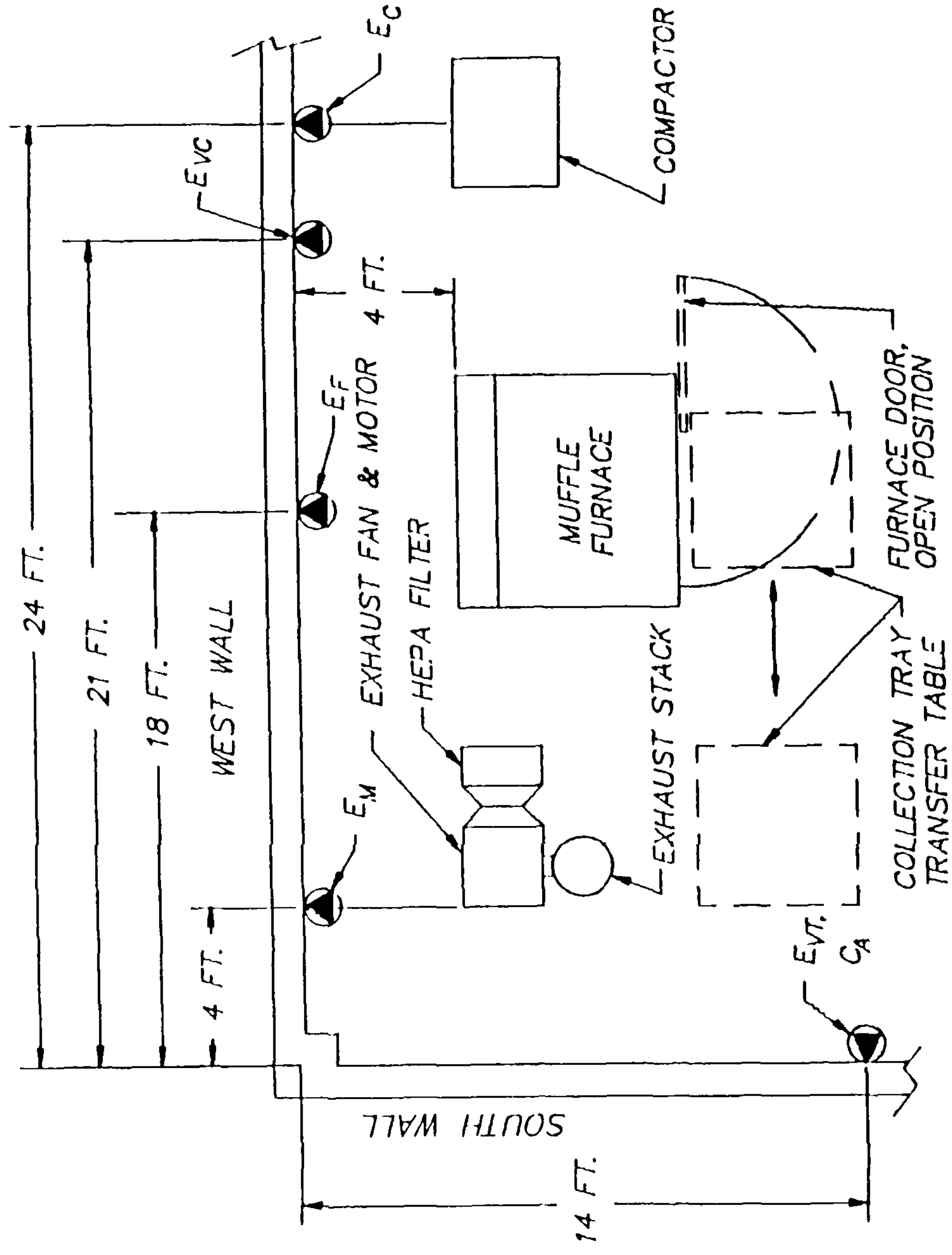


Figure 4. One proposed location for the radwaste processing system equipment. E_M, E_F, E_{VT}, E_C and E_{VC} refer to electrical outlets for the fan motor, furnace, vacuum transfer, compactor and vial crusher respectively; C_A refers to the compressed air outlet.

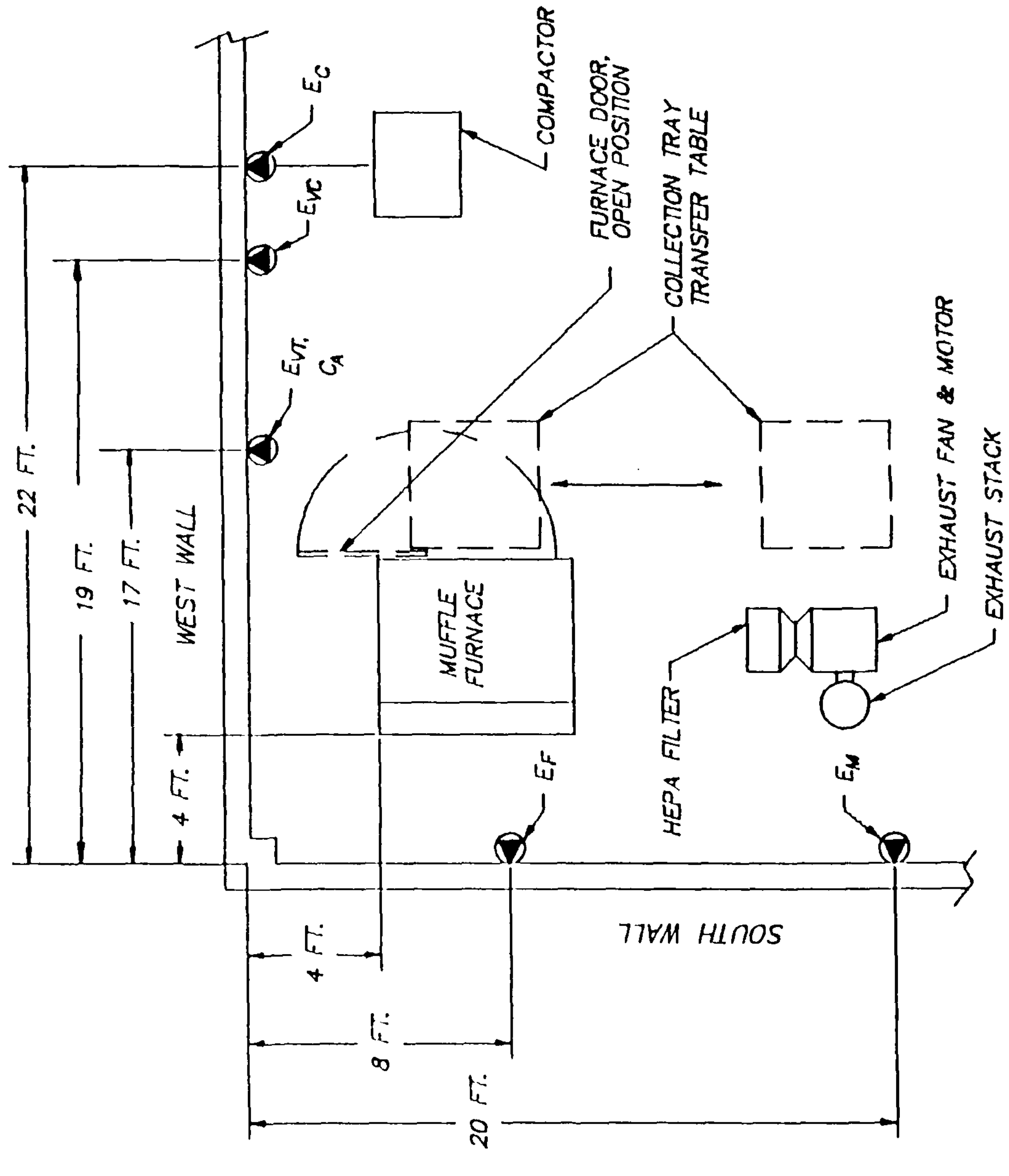


Figure 5. Another possible location for the radwaste processing system equipment. E_M, E_F, E_{VT}, E_C and E_{VC} refer to electrical outlets for the fan motor, furnace, vacuum transfer, compactor and vial crusher respectively; C_A refers to the compressed air outlet.

Compactor

The estimated projected costs for the compactor are shown below:

Costs	Consolidated Bailing, DOS-RAW-W-2	S&G Enterprises, 55 ER	Container Products, D-40
	Manufacturer and Model		
Cost	$24,375	$32,000	$43,412
Delivery	500	500	500
Installation	3,000	3,000	3,000
Totals	$27,875	$35,500	$46,912

Vacuum Transfer

The estimated projected costs for the vacuum cleaning system also varies with manufacturer, and is shown below (the totals include delivery and installation at ARDEC):

Hako Minuteman Model X-703-55	$3838
Nilfisk of America Model GS 82	$5025

Vial Crusher

The estimated projected costs for the vial crusher including mounting attachments, delivery and installation is $2664.

Design and Construction Schedules

Muffle Furnace

The muffle furnace is a custom design, and no standard models are available. While different fabricators will probably require varying construction times, Koppenaal & Associates could deliver the muffle furnace in about twelve to sixteen weeks.

Compactor

The compactor is an existing, commercially available model, and as a result, the design already exists. The construction schedule varies with manufacturer as follows:

Consolidated Bailing	10 weeks
S & G Enterprises	6 weeks
Container Products	7 weeks

Vacuum Transfer

The vacuum cleaning system is also a commercially available model, and the construction time including delivery is shown below:

Hako Minuteman	5 weeks
Nilfisk of America	4 weeks

Vial Crusher

The vial crusher is also a commercially available model, but the mounting fixturing would have to be specially constructed. The construction time and delivery for the complete unit is estimated at eight weeks.

Facilitation Plan

Procurement

Muffle Furnace. The Muffle furnace should be ordered to meet the requirements of the specification contained in Appendix I. The following companies are recommended as potential suppliers of the muffle furnace system:

1. Koppenaal & Associates
   21095 Whitebark
   Mission Viejo, CA 92692
   (714) 583-1700

2. Misco Industrial Furnaces
   6530 East Alondra Blvd.
   Paramont, CA 90723
   (213) 634-2314

3. Thermal-Vac Technology
   1221 West Struck Avenue
   Orange, CA 92667
   (714) 997-2601

Compactor. The compactor should be ordered to meet the requirements of the specification contained in Appendix II. The following three vendors are recommended as potential suppliers for the compactor:

1. Consolidated Baling Machine Company
   156-166 Sixth Street
   Brooklyn, NY 11215-3193
   (718) 625-0928

2. S & G Enterprises, Inc.
   5626 North 91st Street
   Milwaukee, WI 53225
   (414) 464-5310

3. Container Products Corporation
   P. O. Box 3767
   Wilmington, NC 28406
   (919) 392-6100

Vacuum Transfer. The vacuum transfer should meet the requirements previously discussed. The following two companies are recommended as suppliers:

1. Hako Minuteman, Inc.
   111 South Route 53
   Addison, IL 60101
   (312) 627-6900

2. Nilfisk of America, Inc.
   300 Technology Drive
   Malvern, PA, 19355
   (215) 647-6420

Vial Crusher. The vial crusher should meet the requirements established in the engineering specification, Appendix III. Two recommended supplier are shown below:

1. C. S. Bell Company
   170 West Davis Street
   Tiffin, Ohio 44883
   (419) 448-0791

2. B/R Instrument Corporation
P. O. Box 7
Pasadena, Maryland 21122
(800) 922-9206

Installation

In determining the efforts required for installation, we have assumed that the necessary services described previously have been brought into the building.

Muffle Furnace. The muffle furnace will require uncrating, assembly, electrical connection, and ventilation ductwork. About ten man-days of labor and about $1000.00 for materials (electrical connections) will be required for the installation of the furnace.

Compactor. The compactor will require uncrating, positioning in place and electrical connecting. About two man-days of labor and $500.00 for materials (electrical connection) would be required for installing the compactor.

Vacuum Transfer. In addition to plugging into an electrical connection, the vacuum transfer system needs to be connected to a compressed air outlet. About one man-day and $500.00 for materials would be required for the installation.

Vial Crusher

The vial crusher will require uncrating, positioning in place and electrical connecting. About one man-day of labor and $500.00 for materials (electrical connection) would be required for installing the vial crusher.

Start-Up Testing

Muffle Furnace. The testing for the muffle furnace is relatively simple. The following procedure is recommended as a test:

Turn on the "On" switch and heat to 800 degrees F (427 degrees C), hold for 1/2 hour, heat to 1200 degrees F (649 degrees C), hold for 1/2 hour, heat to 1600 degrees F (871 degrees C), hold for 1/2 hour, cool to ambient.

Compactor. The testing plan for the compactor consists of testing at the suppliers site prior to shipment and again at ARDEC upon completed of installation. The following tests are recommended for being done at the manufactures facility prior to shipment.

a. 55-Gallon Drum Use

Verify that the drum support plate and roller extension are in operating order and correctly aligns drum for compaction.
Verify that the platen properly descends inside the drum.

b. 85-Gallon Drum Use

Verify the same items listed for the 55-gallon drums in "a" above.
Verify that that an 85-gallon drum fits inside the compaction chamber with the outer door completely closed.

c. Electrical Controls

Verify that the ram "up" and "down" controls automatically turns on the ventilation system.
Verify that the ventilation system has a separate manual shut off switch.
Verify that the pump motor shuts off at the end of each cycle.

verify that the "down" control locks the platen at the end of the compression stroke to keep the material under pressure until the next loading.

d. Interlocks

Verify that all mechanical and electrical interlocks are in operating order to prevent injury during the compression stroke.
Verify that the interlocks cannot be easily by-passed.

e. Ventilation System

Verify that the air flow complies with the specifications.

After installation at ARDEC is completed, the testing outlined in sections c, d and e above should be repeated.

Performance Specifications

The testing outlined below assumes that the installation and start-up testing have been completed.

Muffle Furnace

The following testing is being recommended to determine the performance of the muffle furnace. The processing is a two stage cycle with ashing or charring being done during the first stage in the absence of oxygen, and complete passivation being done with a controlled amount of oxygen during the second stage. NOTE: ALL TESTING DURING THE PERFORMANCE EVALUATION IS TO BE DONE WITH SIMULATED (NON-RADIOACTIVE) WASTES.

a. Load collecting tray with one pound, .45 Kg., (1/30 of rated capacity) of non-radioactive wood and paper. Place tray in furnace and close door.

b. Close air inlet. No oxygen is to enter chamber during the first ashing (charring) cycle.

c. Heat to 1200 degrees F (649 degrees C) at 50 degrees F per hour (28 degrees C per hour).

d. Hold at 1200 degrees F (649 degrees C) for 4 hours. Cool to ambient with either forced cooling or natural cooling.

e. Ensure that the pressure release valve is open and that the air pressure inside chamber is at atmospheric pressure.

f. Open door, remove collecting tray and inspect wood/paper. Torch test to determine extent of ashing.

g. Reload furnace with ashed material, and heat to 1200 degrees F (649 degrees C) in two hours. After stabilizing, heat to 1600 degrees F (871 degrees C) at 50 degrees F/hour (28 degrees C/hour) with inlet of 1 CFM of air.

h. Hold at 1600 degrees F (871 degrees C) for 4 hours. Cool to ambient. Maintain air inlet of 1 CFM during entire cycle, including cooling to ambient.

i. Check to ensure pressure inside chamber is at one atms.

j. Open door, remove collecting tray and inspect material. Torch test to determine extent of ashing.

k. Repeat steps a-j above with about 7-lbs. (3.2 Kg) of wood and paper. Adjust heating rates, holding times and temperatures as desired, based upon results of previous evaluation.

l. Repeat steps a-j above with the design capacity of 30-lbs. (13.6 kg) of wood and paper. Adjust heating rates, holding times and temperatures as desired, based upon results of second evaluation.

m. If desired, steps a-j above can be repeated with other loads of rated capacity (30-lbs) using adjusted heating

rates, holding times and temperatures for as many times as felt necessary to establish a final processing cycle.

After these evaluations are completed, the ability of the furnace to meet the performance requirements (with simulated radioactive wastes) will be known.

Compactor

The following testing is being recommended for establishing the performance of the compactor.

a. Verify that the correct efficiency HEPA and prefilters are being used.

b. Using simulated (non-radioactive) trash, verify that a 5:1 volume reduction can be obtained.

c. If desired, verify that a non-radioactive HEPA filter can be compacted using an 85-gallon drum.

Vacuum Transfer

The performance of the vacuum transfer system can be evaluated with the following tests.

a. Verify that the correct efficiency HEPA and prefilters are being used.

b. Using simulated (non-radioactive) ashed wastes, verify that the wastes can be transferred from the collection tray to a 55-gallon drum.

Vial Crusher

The performance of the vial crusher can be evaluated with the following test.

a. Using empty, non-radioactive 20mm vials, verify that a 5:1 volume reduction can be accomplished.

CONCLUSIONS

A systems engineering review and design for a small scale laboratory low-level radwaste processing system has been performed, and the program has produced the following conclusions.

Waste Disposal Plan

A small research laboratory low-level radwaste processing system has been established for all the radioactive materials of concern to ARDEC. The materials have been grouped into one of eight categories (ashing/passivation, compacting, crushing, filters, non-burnable/non-compactable, evaporable liquids, non-evaporable liquids and recycling), and a volume reduction process prepared for each category (where applicable).

Meeting Requirements

The radwaste processing system meets all known technical, legal and safety requirements.

Application To Non-Radioactive Wastes

The radwaste processing system can also be used for the volume reduction of similar but non-radioactive wastes.

Application To Other Army Facilities

The radwaste processing system developed for ARDEC could also be used by other Army facilities.

Muffle Furnace Design

A laboratory scale muffle furnace has been designed that meets all ARDEC requirements for the ashing/passivation of radioactive, burnable materials (that do not produce toxic products of combustion). The expected volume reduction of wastes processed in this furnace is 25:1. When used for the evaporation and subsequent passivation of evaporable liquids, including both aqueous solutions and pump oil contaminated with depleted uranium, the expected volume reduction is over 100:1 In both cases, the system is expected to completely passivate over 99% of the pyrophoric, unoxidized depleted uranium. As a result, the ashing/passivation not only gives a very significant volume reduction, but it also greatly improves upon the safety of the overall waste disposal plan.

Compactor

Commercially available models of compactors are available that meet all ARDEC requirements for the volume reduction of radioactive wastes. The expected volume reduction of wastes processed by compaction is 5:1.

Vial Crushing

Commercially available models are also available for vial crushers to volume reduce liquid scintillation vials. The expected volume reduction for these vials is 5:1.

Location Within ARDEC

The radwaste processing system can be installed in Building 312 at ARDEC. Only electricity and compressed air are required for the operation of the system; water and some type of heating are also recommended for non-system needs.

Waste Disposal Savings

The radwaste processing system established here will result in a savings of over thirty-two thousand dollars annually, which represents an ninety-three percent reduction of the present costs.

RECOMMENDATIONS

Radwaste Processing At ARDEC

Since all of the goals of the Phase II program have been met, it is strongly recommended that the treatment of low-level radioactive wastes at ARDEC be performed with a small research laboratory scale processing system after the completion of two additional phases (described in the following two sections).

Phase III

Phase III would have three main tasks. The first would be a data acquisition program to establish the expected time-temperature relationships for ashing/passivation each type of applicable radwaste. Only simulated radwastes would be used for this program, but all other factors would be the same as planned for the actual processing system.

A second task would be to evaluate and establish a technique for a solidification process. The ashed/passivated wastes produced from the first task would be used to develop the solidification process.

The third task would be to finalize the pre-procurement of the necessary components of the radwaste processing system. This would include preparing a list of the specific equipment that is required and obtaining current cost estimates along with fabrication and installation schedules.

Phase IV

Phase IV would be a procurement and performance verification program. The optimum procurement would probably be a "turn-key"

installation for the entire system, but each individual component could be procured separately. Prior to receipt of any of the equipment, a final system layout would be required.

After each component is received and installed, the performance program outlined in this report would be accomplished. The initial evaluations would be done with simulated radwastes, and only after the performance had been documented with simulated radwastes would the actual processing of radwastes be undertaken.

Phases III and IV could obviously be combined into one program, as desired.

Other Considerations

Should the proposed low-level radwaste processing system not be developed at ARDEC, the system design for ashing/passivation, compaction and evaporation of radwastes would not be evaluated for use at installations in addition to ARDEC that are confronted with an ever increasing volume and costs for disposing of wastes contaminated with low level radioactivity.

APPENDIX A

FIRE PROTECTION PRECAUTIONS FOR HANDLING URANIUM TURNINGS, CHIPS, BORINGS SAWDUST AND POWDER

by

Edward J. Kehoe
Francis L. Brannigan
Merril Eisenbud

FIRE PROPERTIES

Uranium metal is pyrophoric which means that in finely divided form it may ignite spontaneously on contact with air. While this reaction may occur regardless of whether the uranium powder is dry or moist, it occurs more readily in the latter state at slightly elevated temperatures. The dried uranium powder can also be ignited by rough handling. Uranium turnings and chips are easily ignited by an outside source of ignition.

The term "uranium scrap" is used in this paper to include uranium turnings, chips, borings, sawdust and powder. Such miscellaneous scrap may include material of all sizes from dust to turnings, in addition to oil, water, and foreign matter such as floor scrapings, organic waste, etc.

STORAGE

The amount of uranium scrap in storage should be kept at a minimum. Protection is increased through isolation and separation of the material on hand into small batches. Fire resistive storage facilities are recommended.

The temperature of a mass of burning uranium approaches 2300 degrees F; accordingly, it is necessary to isolate uranium storage from other combustible materials.

Scrap may be stored under a mineral oil or water. However, in the case of the water, provision must be made for the safe ventilation of the resultant hydrogen gas since the scrap slowly oxidizes in contact with water releasing free hydrogen. Consequently, storage under a mineral oil is generally preferred to storage under water.

The storage of scrap only partially submerged in oil or water is dangerous. Ignition is very apt to occur at the liquid line. The

reaction is particularly severe in the case of water since the water boils off through the mass of burning metal with the liberation of large quantities of hydrogen. (Remember that hydrogen has an unusually wide explosive range, 4% to 75%). In one such fire, involving an insufficiency of water, holes were burned through a metal drum by the fire and hydrogen flames several feet long shot out in addition to flames ten feet high from the top of the drum. If the liquid is oil, it to will probably ignite and add to the fire. By all means, avoid leaving exposed to air, scrap just moist with oil or water.

When not stored properly, as for example when only partially covered with oil or water, incipient spontaneous ignition can usually be detected by the heating of the container; there is usually a marked increase in temperature which can be detected by the hand for some time prior to ignition.

Automatic sprinkler systems provide satisfactory protection for uranium turnings, chips and borings and for the small quantities of sawdust or powder generally encountered in a machine shop or laboratory; while hydrogen is evolved from the water, it burns off readily under control and the sprinklers prevent the extension of the fire. In the unusual cases where extremely large quantities of uranium dust or powder may be involved, an inerting system utilizing a gas which is non-reactive with uranium, such as argon, may be in order.

LABORATORY HANDLING

In handling uranium scrap, every possible source of heat or spark should be eliminated. It is advisable to handle the material wet or under an argon atmosphere. Specially constructed explosion safe argon dry boxes have been found very satisfactory where extremely pyrophoric forms are involved. Actually, extremely pyrophoric forms or uranium powder may burn so rapidly as to have effect of an explosion.

If for some reason ordinary laboratory glassware is used in lieu of such

a dry box, safety glass screens and face shields are minimum protection. The work area should be kept clean of flammable liquids and other materials which might cause fires which would spread to the uranium. Quantities exposed at any time should be kept to a minimum.

SAFE DISPOSAL OF URANIUM SCRAP

[This section is now obsolete and is not reproduced.]

INTERSTATE COMMERCE COMMISSION REGULATIONS

[This section is also obsolete and is not reproduced.]

FIRE CONTROL

The best fire protection for uranium scrap is provided by keeping quantities small and separated, by segregating the scrap from other flammable materials, and by handling and storing uranium in locations suitable for permitting a fire to burn out.

Fires in machining operations can be avoided by prompt removal of scrap out of the region where glowing turnings fall. Formation of a heavy oxide layer will extinguish the combustion of an isolated metal turning. If a small fire occurs it can be extinguished by a gallon or so of the coolant; for this purpose an open top can of the coolant should be kept at hand.

G-1 powder (a commercial preparation with a graphite base), graphite chips, powered talc or dry sand are useful in uranium scrap fires for controlling radiant heat, spatters and fumes. A supply of at least one of these agents should be available at all locations where uranium scrap is handled.

Ordinary fire extinguishers are not suitable. Uranium powder can burn in an atmosphere of carbon dioxide (which eliminates carbon dioxide

extinguishers) are reacts to nitride in an atmosphere of nitrogen. The reaction with carbon dioxide also precludes dry chemical since such extinguishers depend on the heat of the fire liberating carbon dioxide from the breakdown of the bicarbonate of soda. Carbon tetrachloride extinguishers should not be used because of the undesirablility of releasing carbon tetrachloride fumes in a confined space and because the hot metal present may possibly cause decomposition of the carbon tetrachloride. Soda-acid and foam extinguishers are not recommended since they may cause scattering of the burning material and at best require extremely skillful handling to have any beneficial effect on burning uranium. Hose streams should be avoided. However, as mentioned in the section on "Storage," automatic sprinklers are satisfactory unless an extremely large quantity of powdered uranium is involved; this would by no means constitute the usual situation.

Inhalation of the fumes from burning uranium metal should be avoided. If the burning occurs under controlled conditions, such as the burning of a small quantity in a laboratory, the hoods ordinarily used in handling the uranium will provide sufficient ventilation. However, if the burning does not take place under controlled conditions, an approved breathing apparatus should be worn.

APPENDIX B

ENGINEERING SPECIFICATION FOR A MUFFLE FURNACE

PURPOSE

The muffle furnace is to be used for the complete ashing-passivation of low-level radioactive materials including, but not restricted to, unoxidized, pyrophoric depleted uranium and tritium. In addition to solids, the muffle furnace will also be used to evaporate and passivate both aqueous solutions and pump oil contaminated with unoxidized, pyrophoric depleted uranium.

HEALTH PHYSICS REQUIREMENTS

Notwithstanding any engineering design or feature contained in this specification, the operation of the muffle furnace along with the effluents produced by the furnace MUST meet the requirements of the Nuclear Regulatory Commission, OSHA and any other appropriate regulatory agency. This includes, but is not restricted to, the release of radioactivity from depleted uranium in excess of 2×10^{-12} μCi/ml (see DOE Order 5480.1, Attachment XI-1, Table II) and the release of radioactivity from tritium in excess of 2×10^{-7} μCi/ml.

FURNACE ENGINEERING REQUIREMENTS

General Features

The muffle furnace has a sealed working chamber that is surrounded by heating elements and insulation. The sealed chamber has an access door with various inlet and exit ports.

Capacity

The furnace shall have the capacity to process either one 24" by 24" by 12" HEPA filter or a batch load of one cubic foot of low level radwaste (in the case of wood, this amounts to about 30-lbs., or 13.6 Kg).

Type of Heating

The muffle furnace shall utilize electric heating.

Heating Requirements

The furnace shall be capable of heating a cold furnace with a cold load from ambient to 2000 degrees F (1093 degrees C) in 1-1/2 hours.

Cooling Requirements

The work load must be able to cool down from 2000 degrees F (1093 degrees C) to 150 degrees F (66 degrees C), or lower, in two hours. An auxiliary blower of sufficient size and pressure, piped through a diffuser into the heating element chamber shall be provided for the cooling. The exit damper is to be fully automatic when the cooling blower is actuated.

Shell and Frame

Drawing 8801 shows front and side views of the shell and frame of the furnace. The shell and frame shall be fabricated from 1/4-inch thick mild steel. The construction shall be of sufficient strength to provide distortion free service life and allow for shipping and rigging. Two coats of high temperature paint shall be applied.

Working Chamber

The working chamber is to accommodate a work basket measuring 30" wide x 30" long x 15" high. Drawing 8802 shows the chamber; the chamber has corrugations that run lengthwise on the bottom, and vertical corrugations on the sides, top and back. The chamber shall be fabricated from 11 gage RA 330 alloy

The working chamber must be gas tight (with the plug door in position).

The working chamber temperature uniformity shall be plus or minus 10 degrees F in at least nine different positions in the chamber.

Plug Door

Drawing 8803 shows views of the plug door. The door shall be fabricated from 1/4-inch mild steel plate and eleven 16 gage plates (with spacers between each of these plates).

The plug door shall have an inlet and exit pipe for accommodating controlled inputs and exiting of air, nitrogen and other gases as may be required (size and location of the ports shown in drawings).

The plug door must have one rectangular view port for observing the load during processing and one rectangular view port to provide lighting for loads below 1400 degrees F (size and location shown in drawings).

The plug door shall have an inlet pipe for thermocouples (location in drawings).

The plug door shall produce a gas tight fit with the working chamber.

Inlet/Exit Ports

The furnace shall have one inlet port and one exit port. The inlet port is for the introduction of air, nitrogen and other gases and must be controllable through the range of 1/2 CFM to 20 CFM.

The exit port is for the exhaustion of gases from the input, vaporization of volatile components and/or products of combustion (gases). The amount of exit gas will vary from zero to about 100 CFM. All exit gases must pass through a cooling chamber and cooled to a maximum temperature of 500 degrees F (260 degrees C) before entering the exhaust system.

Both the inlet and exit ports shall have quick release switches to facilitate easy connecting and disconnecting. The switches shall be wired through the main furnace controller such that the furnace cannot be started without both switches being connected.

Drawing 8804 shows a schematic of the air inlet and exit system.

Heating Elements

The heating elements shall be appropriate for use to 2000 degrees F (1093 degrees C). Alloys such as NiChrome or Tophet-AA are satisfactory.

An silicon controlled rectifier (S.C.R.) drive system shall be used to control the heat output of the heating elements.

After Burner Chamber

The after burner chamber is about two feet in diameter and about two and one-half feet long. An electrically heated grid is located in the front of the chamber, and all gases originating in the furnace must pass through the heated grid via the exit port. This grid is heated to about 1600 degrees F (871 degrees C), and is operational at all times the muffle furnace is in a heating mode of operation. The grid ignites all volatile gases which are then pulled through an eductor (by a venturi effect) powered by the exhaust fan. The burned gases are highly diluted with ambient air. Drawing 8804 includes a schematic drawing of the after burner chamber.

Insulating Refractory

The insulating material shall be of good quality and light weight. The insulation shall maintain the outside walls of the furnace at 150 degrees F (66 degrees C) for an inside temperature of 2000 degrees F (1093 degrees C) with zero wind velocity and ambient air at 80 degrees F (27 degrees C). Ceramic fiber is a satisfactory insulating material.

Control Cabinet

The control cabinet can be floor standing or attached to the furnace.

The control cabinet shall have all the necessary audio and visual warning devices as necessary to meet all safety, OSHA and other requirements.

The following temperature control instruments shall be provided:

Temperature Controller

A fully programmable temperature controller shall be provided. The controller shall be capable of providing full variable temperature control to ramp up, hold and cool down, as required. The controller shall be capable of incorporating multiple programs. Only moderate skill shall be required for setting the controller and only low skill shall be required for running the controller. The temperature controller shall read degrees F or degrees C, as specified (or in both temperature scales, if specified).

Chart Recorder

A temperature chart recorder shall be provided to record the total heat cycle from start to finish. It is anticipated that 24 to 48 hour processing cycles will be used.

Over Temperature Control

An over temperature control instrument shall be provided to protect the furnace from accidental over heating to dangerous or destructive temperatures. A warning light and signal horn will also be provided.

Collection Tray

The collecting tray has been sized to accommodate a 24-inch by 24-inch by 12-inch HEPA filter; drawing 8805 shows the collection tray. The tray is fabricated from 11 gauge 330 stainless steel, and continuous welding is used for the walls. The collection tray must be watertight since one of its uses is for evaporating aqueous solutions. All inside surfaces of the collection tray are coated with an appropriate ceramic (this is necessary because uranium and iron form an eutectic at about 1500 degrees F, 816 degrees C).

The maximum capacity of the collection tray is 30-lbs. (13.6 Kg) of dry solids. When used to evaporate contaminated liquids, the collection tray shall have a capacity of 325-lbs. (148 Kg.), which represents the weight of liquid to a depth of ten inches; the tray shall be capable of retaining this weight of liquid up to a temperature of 212 degrees F (100 degrees C).

Collection Tray Transfer Table

A transfer table shall be provided for removing the collection tray from the furnace; the transfer table shall be able to support the weight of the collection tray with its maximum capacity.

The collection tray transfer table is 36-inches wide by 36-inches long by approximately 31-1/2-inches high; the height of the transfer table must be adjustable in order to match the inside surface height of the floor of the muffle. The table has nine 2-inch diameter rollers that are parallel to the furnace face to facilitate rolling the collection tray from the furnace to the transfer table. The four legs of the table have swivel wheels for ease of positioning in front of the furnace for removal of the collection tray. As an option, rails can be affixed to the building floor and four grooved wheels used for a straight line positioning of the table; note that this does not give as much freedom in positioning the table when not being used for transferring. Drawing 8806 shows the collection tray transfer table.

FURNACE VENTILATION REQUIREMENTS

The muffle furnace shall be equipped with a ventilation system that contains a HEPA filter. The following components are required:

HEPA Filter

The ventilation system shall contain one 24" x 24" 12" wide HEPA filter that has a minimum filtering efficiency of 99.99% of particles 0.2 micron and larger. The filter shall maintain containment at temperatures up to 1000 degrees F (538 degrees C). The filter housing shall be fabricated from stainless steel and shall be of the "bag-out" design. A pressure differential gauge with an audio alarm shall be included to determining the filtering capability.

In addition to the HEPA filter, the system shall contain one pre-filter with a minimum filtering efficiency of 40% for particles 0.2 microns and larger. The pre-filter is located in front (upstream) of the HEPA filter.

Exhaust Fan and Motor

The ventilation system shall contain and exhaust fan with a capacity of 1000 CFM and a 5 HP motor to drive the fan (belt drive).

Ductwork

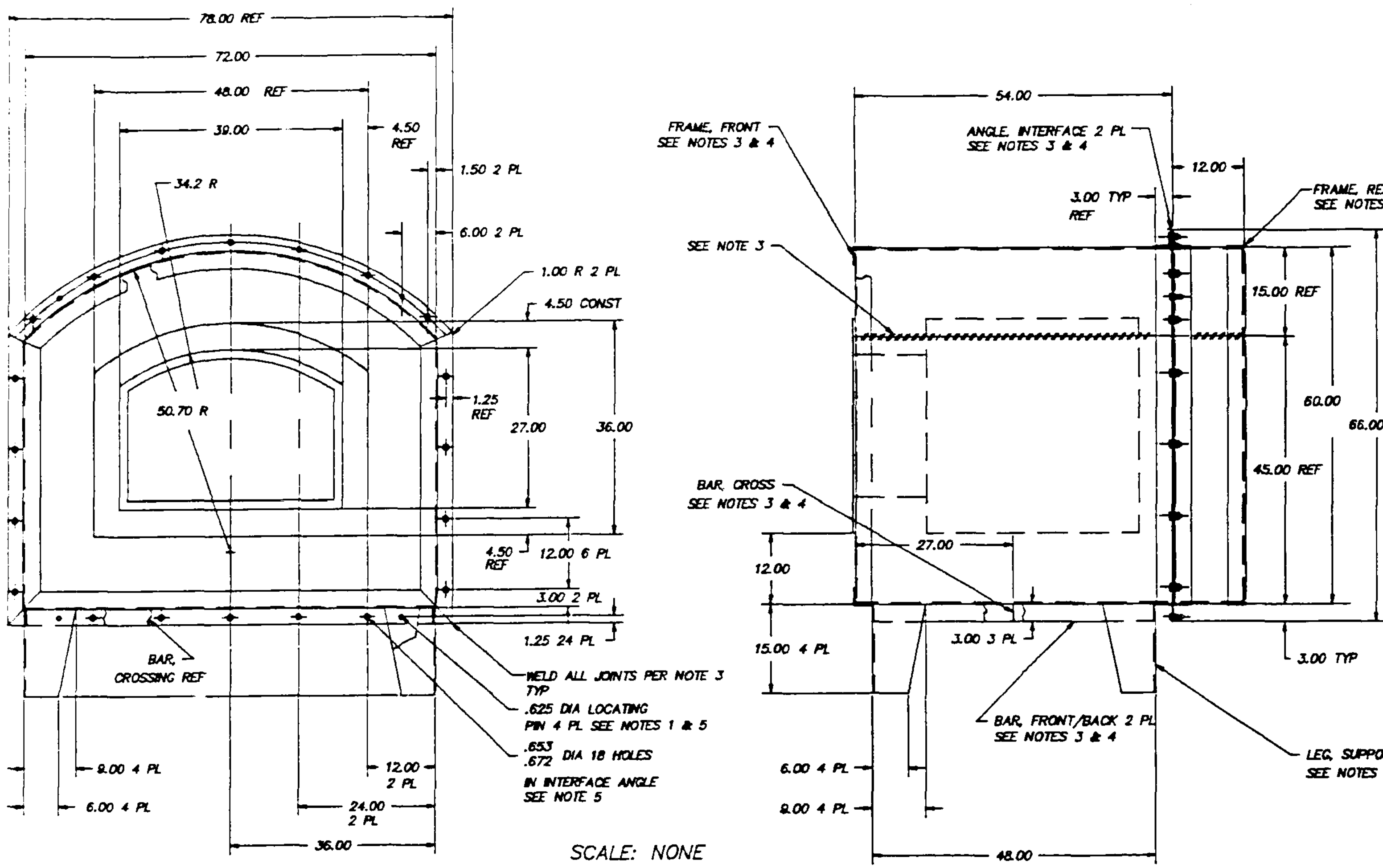
The ventilation shall utilize ten inch diameter stainless steel ductwork and all duct joints shall be welded.

Controls

The ventilation system shall be equipped with controls for the normal operation of the system.

EASE OF OPERATION

The operation of the furnace including the temperature controller and ventilation system shall be (a) easy to learn and use, (b) operational without skill or experience, (c) operational by personnel not familiar with programming the temperature controller, and (d) operational with minimal learning.



SCALE: NONE

NOTES:
1. LOCATING PINS ARE FOR POSITIONING BACK CAP TO FURNACE SHELL
2. .625 DIA BOLT, NUT AND WASHER ASSY.
3. CONTINUOUS WELD TYPICAL, EXCEPT BARS ARE TO BE SKIP WELDED AS REQUIRED TO OBTAIN FULL STRENGTH SUPPORT OF BOTTOM OF FURNACE
4. MAKE FROM .250 THICK 3X3 90° MILD STEEL ANGLE
5. LOCATE HOLES ON ASSY
6. MATERIAL: BASIC MATERIAL IS .250 INCH THICK MILD STEEL PLATE (SEE SPECIFICATION)

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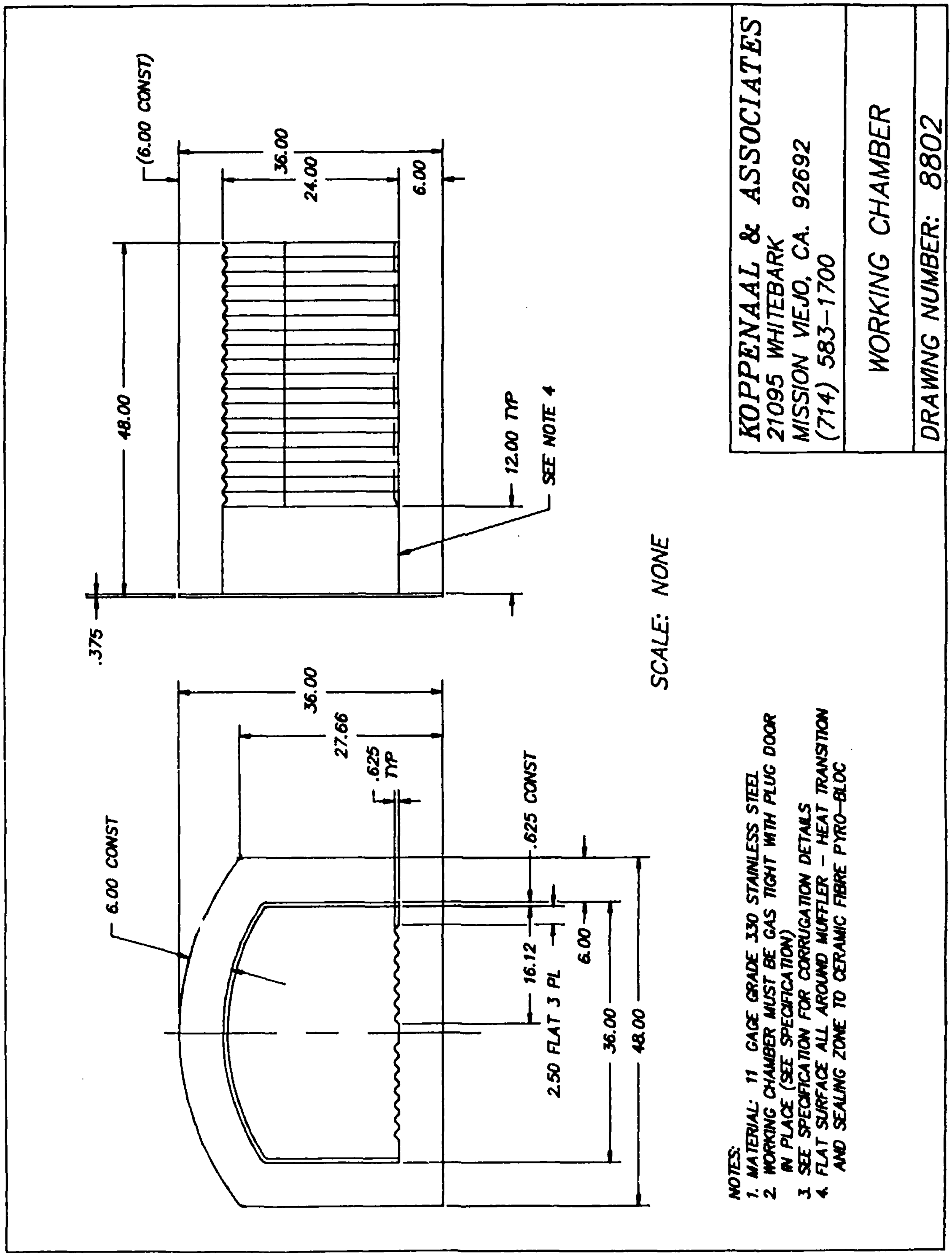
MUFFLE FURNACE
FRAME AND SHELL

DRAWING NUMBER: 8801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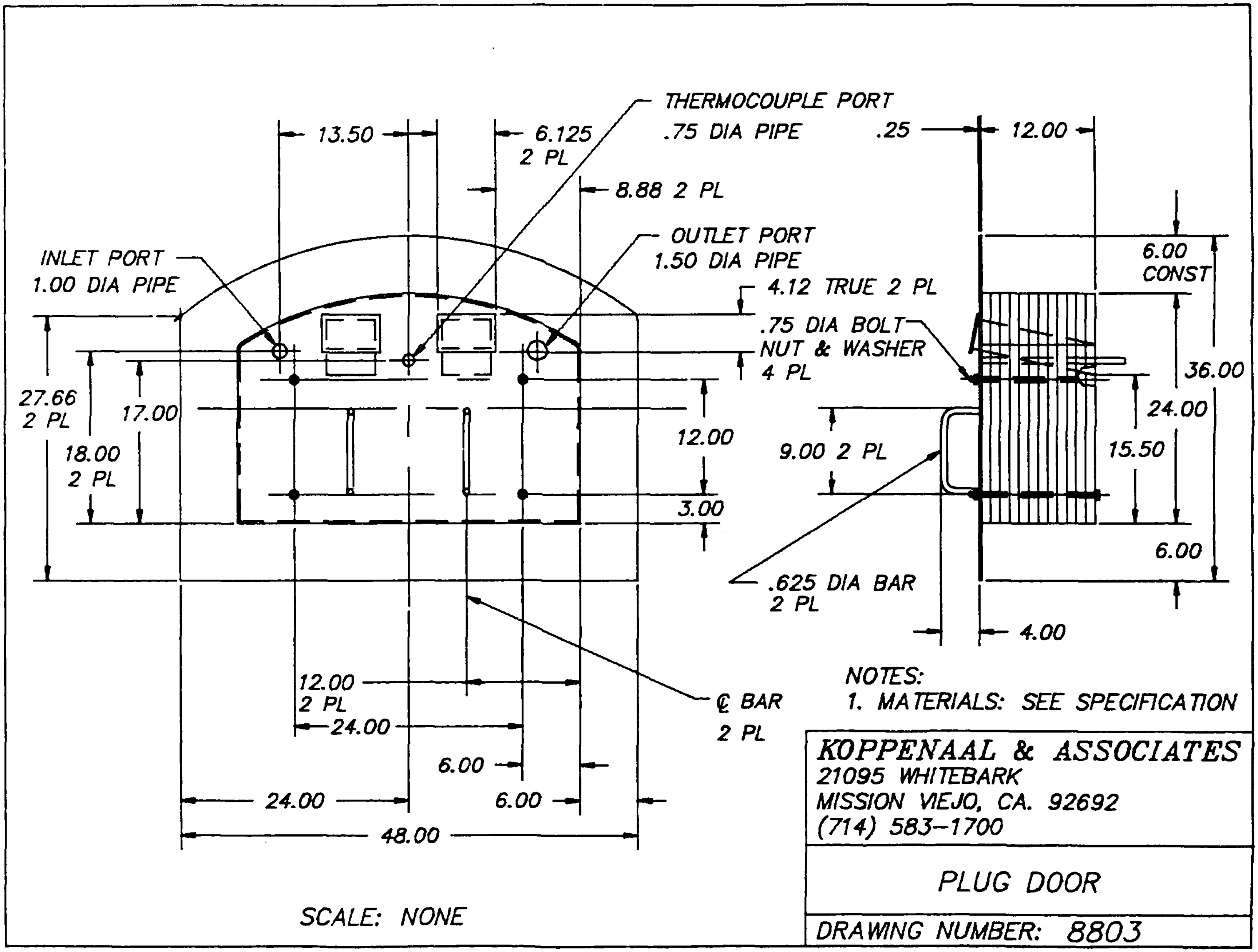
WORKING CHAMBER
DRAWING NUMBER: 8802
SCALE: NONE
(6.00 CONST)
36.00
24.00
6.00
48.00
12.00 TYP
SEE NOTE 4
.375
36.00
27.66
.625 TYP
.625 CONST
6.00 CONST
16.12
6.00
2.50 FLAT 3 PL
36.00
48.00
NOTES:
1. MATERIAL: 11 GAGE GRADE 330 STAINLESS STEEL
2. WORKING CHAMBER MUST BE GAS TIGHT WITH PLUG DOOR IN PLACE (SEE SPECIFICATION)
3. SEE SPECIFICATION FOR CORRUGATION DETAILS
4. FLAT SURFACE ALL AROUND MUFFLER - HEAT TRANSITION AND SEALING ZONE TO CERAMIC FIBRE PYRO-BLOC


THERMOCOUPLE PORT
.75 DIA PIPE
.25
12.00
13.50
6.125
2 PL
8.88 2 PL
OUTLET PORT
1.50 DIA PIPE
INLET PORT
1.00 DIA PIPE
4.12 TRUE 2 PL
.75 DIA BOLT
NUT & WASHER
4 PL
6.00
CONST
36.00
24.00
15.50
27.66
2 PL
17.00
18.00
2 PL
12.00
9.00 2 PL
3.00
6.00
.625 DIA BAR
2 PL
4.00
12.00
2 PL
24.00
℄ BAR
2 PL
6.00
24.00
6.00
48.00
SCALE: NONE
NOTES:
1. MATERIALS: SEE SPECIFICATION
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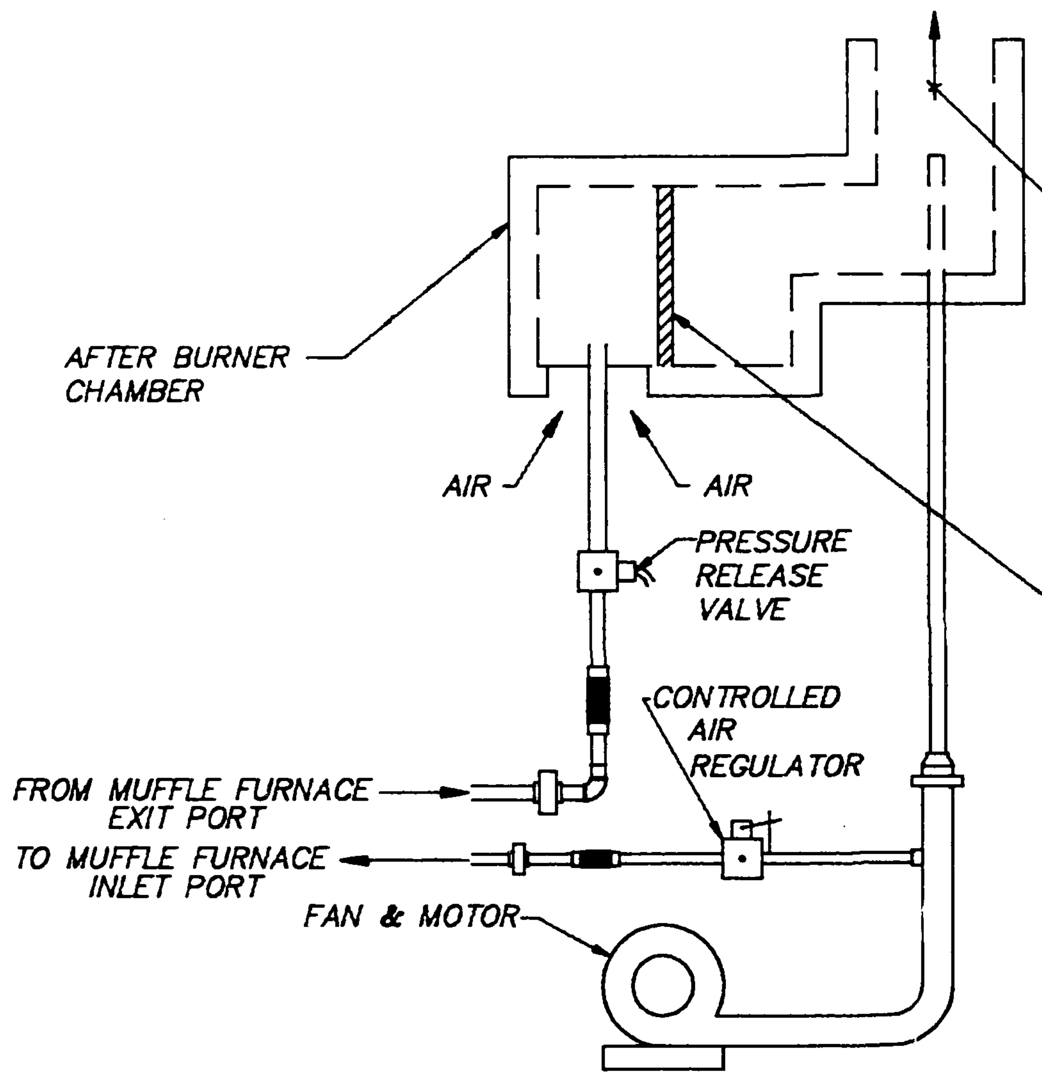
PLUG DOOR
DRAWING NUMBER: 8803



NOTE:
1. SCHEMATIC ONLY

SCALE: NONE

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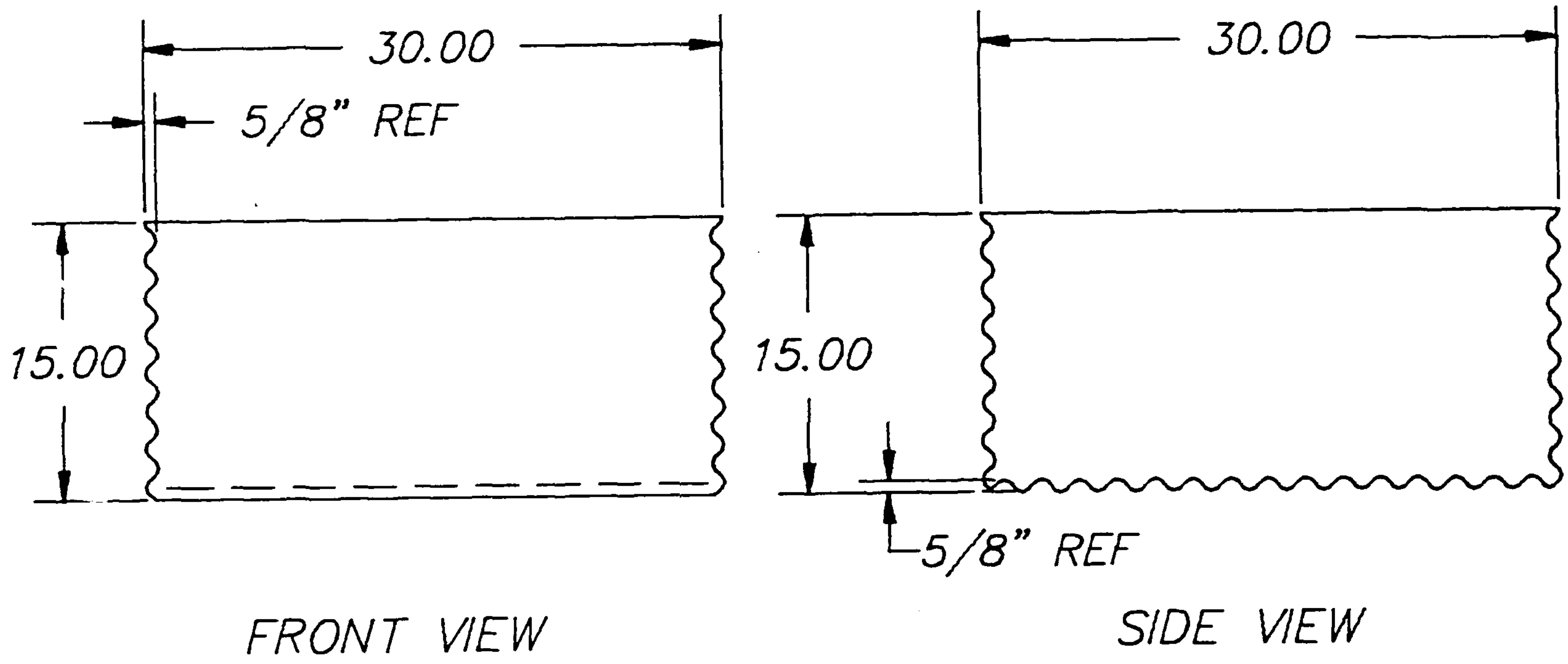
AIR INLET AND EXIT SYSTEM

DRAWING NUMBER: 8804



SCALE: NONE

NOTE:
1. CORRURATIONS ARE 5/8 INCH HIGH AND PEAK ON 2 INCH CENTERS
2. MATERIAL: 11 GAGE, GRADE 330 STAINLESS STEEL. ALL INSIDE SURFACES ARE TO BE COATED WITH A CERAMIC, SEE SPECIFICATION

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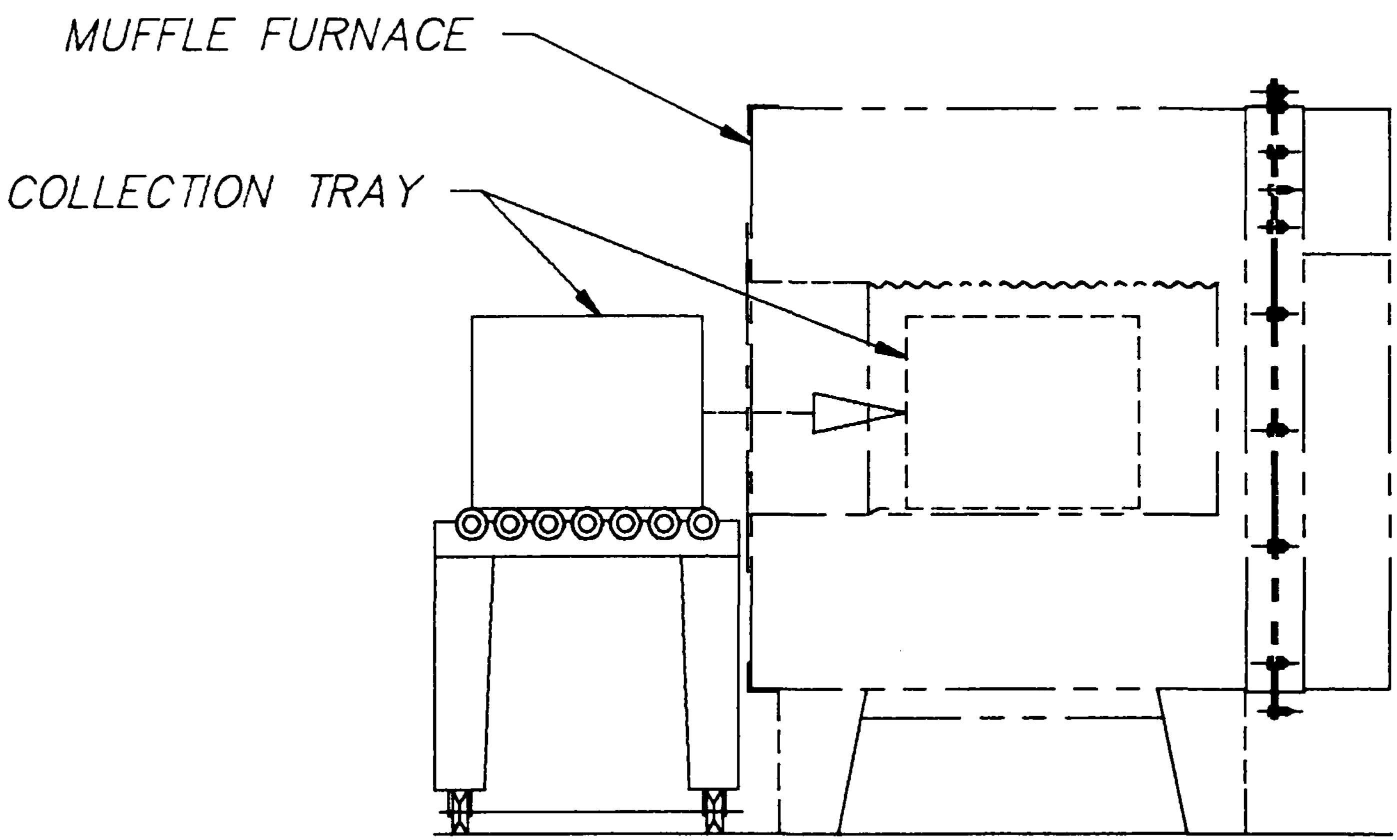
COLLECTION TRAY

DRAWING NUMBER: 8805



NOTE:
1. A. TRANSFER TABLE MOVES PARALLEL TO FRONT OF MUFFLE FURNACE
B. SEE SPECIFICATION FOR SIZE REQUIREMENTS
2. MATERIAL: SEE SPECIFICATION

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COLLECTION TRAY
TRANSFER TABLE

DRAWING NUMBER: 8806

APPENDIX C

ENGINEERING SPECIFICATION FOR A COMPACTOR

PURPOSE

The compactor is to be used for the volume reduction of low-level radioactive materials including, but not restricted to, such items as plastics, leather and ion exchange resins.

HEALTH PHYSICS REQUIREMENTS

Notwithstanding any engineering design or feature contained in this specification, the operation of the compactor along with the effluents from the compactor MUST meet the requirements of the Nuclear Regulatory Commission, OSHA and any other appropriate regulatory agency. This includes, but is not restricted to, the release of radioactivity from depleted uranium in excess of 2×10^{-12} μCi/ml (see DOE Order 5480.1, Attachment XI-1, Table II).

COMPACTOR ENGINEERING REQUIREMENTS

Compression Force

The compactor shall have a compression force of at least 40,000 pounds (20-ton or 18,182 Kg.).

Motor Pump/Electric/Hydraulic Components

The operation of the compactor shall be with a hydraulic system performing the compaction, and this will require a pump, pump motor and various hydraulic and electrical components. The controls shall be designed with "down" and "up" push buttons with a shut-off of the pump motor at the end of each cycle. These push buttons shall also activate the ventilation system blower which shall be designed to continue running until manually stopped. The compression stroke shall result in the material being locked under pressure until the next loading (to reduce any spring-back). The electrical requirement shall be 240 volt (3 phase), 14 KW.

Safety Interlocks

The compactor shall have a safety interlock system that shuts down the system when the compaction chamber door is opened.

Dual Capacity

The compactor shall be able to compact material into either 55-gallon or 85-gallon drums. In addition, it shall be possible to compact 24-inch by 24-inch by 12-inch HEPA filters into the 85-gallon arrangement.

Enclosure

The drums (55 or 85-gallon) shall be completely enclosed inside the compaction chamber during the compaction process.

Construction Materials

The basic compactor shall be of steel at a minimum thickness of 12 gauge, and arc welded construction shall be used. Both the hood used to cover the drums during compaction and the platen used for the actual compaction shall be fabricated from stainless steel. Different hoods and platens shall be provided for compacting into either 55 or 85-gallon drums.

HEPA Ventilation System

The compactor shall be designed with a ventilation system consisting of a pre-filter, HEPA filter, blower and necessary ductwork to provide a minimum of 400 CFM of air flow. The pre-filter shall have a minimum efficiency of forty percent, and a nuclear grade HEPA filter with an efficiency of 99.97% for particles 0.3 micron and larger. The HEPA filter shall have a gauge across the filter for measuring the differential pressure.

Front Extension and Support Plate

The design shall include a front extension and support plate to facilitate installing and removing both 55 and 85-gallon drums.

APPENDIX D

ENGINEERING SPECIFICATION FOR A VIAL CRUSHER

PURPOSE

The vial crusher is to be used for the volume reduction of low-level radioactive materials including, but not restricted to, such items as liquid scintillation vials contaminated with pyrophoric, unoxidized depleted uranium and tritium.

HEALTH PHYSICS REQUIREMENTS

Notwithstanding any engineering design or feature contained in this specification, the operation of the vial crusher MUST meet the requirements of the Nuclear Regulatory Commission, OSHA and any other appropriate regulatory agency. This includes, but is not restricted to, the release of radioactivity from depleted uranium in excess of 2×10^{-12} μCi/ml (see DOE Order 5480.1, Attachment XI-1, Table II) and the release of radioactivity from tritium in excess of 2×10^{-7} μCi/ml.

VIAL CRUSHER ENGINEERING REQUIREMENTS

Capability

The vial crusher shall have the capability of crushing a minimum of sixty 20mm glass vials per hour.

Basic Design Features

The vial crusher shall be a top loading hammer mill with the necessary components to perform crushing of vials containing dry filter paper. The destroyed vials shall be discharged from the bottom and designed to fall into a collection container.

Motor/Electrical Components

The operation of the vial crusher shall be with an electric motor, about 1 HP, 115 or 230 volt AC, single or 3 phase, 60 Hz.

Materials

The vial crusher shall be constructed of stainless steel whereever possible.

Enclosable Feature

Between the feed hopper and the bottom discharge, the vial crusher shall be an air tight system.

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